ACCELERATED BRIDGE CONSTRUCTION (ABC) DECISION MAKING AND ECONOMIC MODELING TOOL

Final Report

PROJECT TPF-5(221)

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by

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16. Abstract

In this FHWA-sponsored pool funded study, a set of decision making tools, based on the Analytic Hierarchy Process (AHP) was developed. This tool set is prepared for transportation specialists and decision-makers to determine if ABC is more effective than traditional construction for a given bridge replacement or rehabilitation project. The tool set is user-friendly, flexible to accommodate a range of construction situations, transparent as to the method of calculation, and customizable to maintain future relevance. To accommodate this task, a comprehensive literature review on a number of relevant domains such as ABC construction techniques and decision making approaches, were completed. The findings were summarized into a decision model hierarchy that was also incorporated into the decision making software. The software was tested through evaluating a set of real-world construction projects.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit	(F-32)/1.8	Celsius	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.196	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius	1.8C+32	Fahrenheit	°F

*SI is the symbol for the International System of Measurement

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State DOT	Members and Titles
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DISCLAIMER

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EXECUTIVE SUMMARY

Accelerated Bridge Construction (ABC) is recognized as an important method to design and rehabilitate highway structures. ABC uses both new technology and innovative project management techniques to reduce the impact of bridge construction projects on the public and to reduce bridge construction costs. In the early stages of a construction project, engineers need to assess whether elements of ABC are achievable and effective for a specific bridge location. Use of decision-making tools in early stages of planning is advocated as a mechanism for helping decision makers assess alternatives with more confidence and for preventing investment in alternatives that are more costly.

In this study, a set of decision making tools, based on the Analytical Hierarchy Process (AHP) were developed. This tool set is prepared for transportation specialists and decision-makers to determine if ABC techniques are more effective than traditional construction for a given bridge replacement or rehabilitation project. The tool set is user-friendly, flexible to accommodate a range of construction situations, transparent as to the method of calculation, and customizable to maintain future relevance. To accommodate this task, a comprehensive literature review on a number of relevant domains, such as ABC construction techniques and decision making approaches, were completed. The findings were summarized into a decision model hierarchy that was also incorporated into the decision making software. The software was tested through evaluating a set of real-world construction projects. The data for these projects were collected by conducting a series of interview sessions.

This project was broken down into three tasks including “Conduct literature review,” “Document current use of ABC,” and “Develop models.” The following report goes over the three tasks that were carried out to develop the best approach in determining suitable alternatives in a bridge project decision making process and to validate the approach using real case studies. The chapters summarizing these three tasks are followed by summaries of the results of the study and the final documents developed as a result of the project. Presentations that have been completed to disseminate the results of this project are also included at the end of the report.

1.0 TASK 1

1.1 WORK BREAKDOWN STRUCTURE

Based on the work statement approved in the January 2010 Technical Advisory Committee (TAC) meeting, the first task planned for the project was initiated. The plan for Task 1 was further broken down into subtasks. These tasks are summarized in Figure 1.1 as a work structure breakdown.

- **1 Task 1**
  - **1.1 Literature Review**
    - **1.1.1 Current state of ABC implementation**
      - 1.1.1.1 Collect all existing reports and presentations
      - 1.1.1.2 Current processes and criteria for decision making
      - 1.1.1.3 Current goals and barriers of using ABC to determine ABC maturity level
      - 1.1.1.4 summarization
    - 1.1.2 Reports on best practices associated with ABC projects
    - 1.1.3 Current propensity for using ABC due to organization culture and industry
    - 1.1.4 Recommendations from ASHTO, NCHRP, RGB, FHWA
    - **1.1.5 Cost estimation studies**
      - 1.1.5.1 Collecting all relevant papers and studies
      - 1.1.5.2 Review economic models and evaluation processes
      - 1.1.5.3 Preliminary ideas for cost estimation model
  - 1.2 Task1 Report

Figure 1.1: Work Structure Breakdown for Task 1

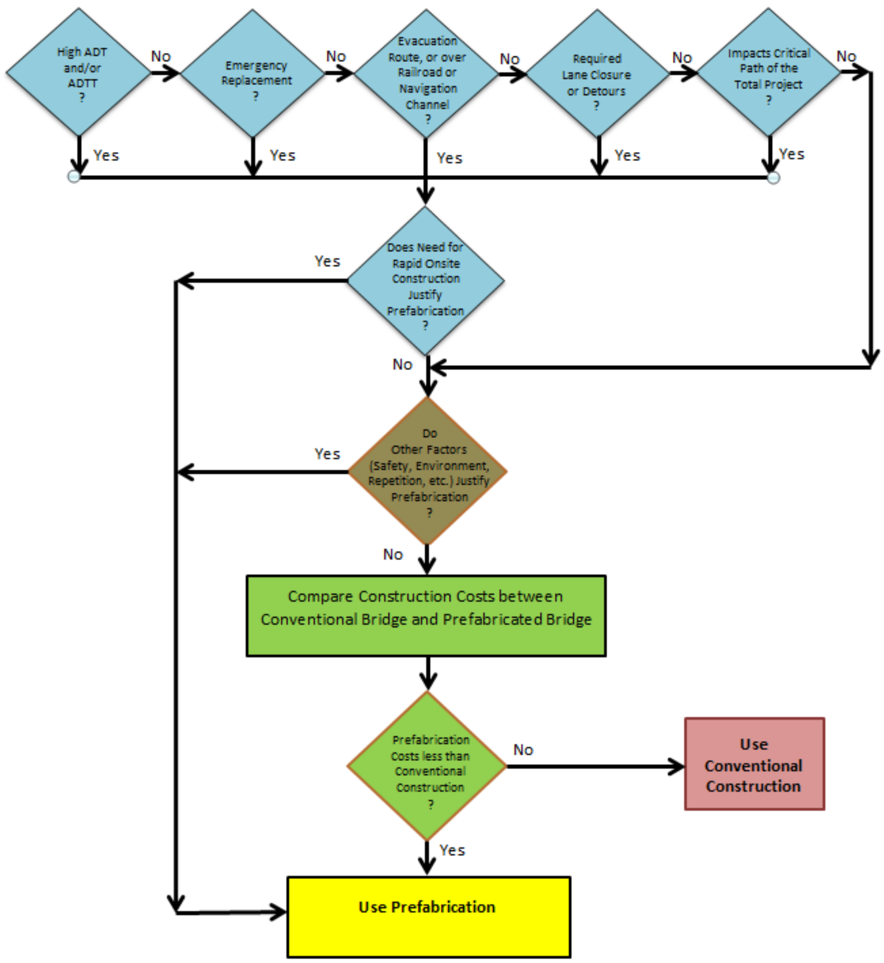
In this step, the research team performed a comprehensive literature review to study the current state of ABC. In this study, more than 40 documents including journal and conference publications, technical reports, theses, and presentations were collected and reviewed. These documents contained reports and presentations that identified the processes used by various state DOTs and other local agencies to implement ABC, summarized best practices associated with successful ABC projects, and confirmed economic models and/or evaluation processes for estimating both the hard and soft costs associated with general construction projects. Studies and recommendations from AASHTO, NCHRP, RBG, and FHWA were also collected. Complete citation information for all of the documents reviewed is summarized in Appendix A. Summaries of each document are also included in Appendix B. Four primary content areas were identified:

- Decision making
- Successful ABC projects
- PBES techniques and innovations
- Cost estimation

1.2 FINDINGS

1.2.1 Decision Making

Three different major approaches for ABC project decision making were identified in the literature. The first approach is based on a framework developed for PBES decision making (*Ralls 2006*). In this framework a flowchart and matrix incorporating a set of decision criteria are used to help decision makers choose between conventional or ABC construction alternatives (*Salem and Miller 2006*). The flowchart assists the users in making a high-level decision on whether a prefabricated bridge might be an economical and effective choice for the specific bridge under consideration. The matrix provides users with a different format and more detail than the flowchart to also assist in making a high-level decision. Figure 1.2 depicts an example of these flowcharts and matrices.



Question	Yes	Maybe	No
Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?			
Is this project an emergency bridge replacement?			
Is the bridge on an emergency evacuation route or over a railroad or navigable waterway?			
Will the bridge construction impact traffic in terms of requiring lane closures or detours?			
Will the bridge construction impact the critical path of the total project?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Is rapid recovery from natural/manmade hazards or rapid completion of future planned repair/replacement needed for this bridge?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Does the local weather limit the time of year when cast-in-place construction is practical?			
Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?			
Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, and noise)?			
Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon nesting?			
If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?			
Can this bridge be designed with multiple similar spans?			
Does the location of the bridge site create problems for delivery of ready-mix concrete?			
Will the traffic control plan change significantly through the course of the project due to development, local expansion, or other projects in the area?			
Are delay-related user costs a concern to the agency?			
Can innovative contracting strategies to achieve accelerated construction be included in the contract documents?			
Can the owner agency provide the necessary staffing to effectively administer the project?			
Can the bridge be grouped with other bridges for economy of scale?			
Will the design be used on a broader scale in a geographic area?			
Totals:			

Figure 1.2: Decision-Making flowchart and matrix
(*Framework for Prefabricated Bridge Elements and Systems Decision-Making, FHWA 2005*)

The matrix may be used in conjunction with or as an alternative to the flowchart. A more in-depth discussion of various factors may be conducted using the 'list of considerations' included in PBES Decision Making framework (*Ralls 2006*).

The second approach presents a method for evaluating bridge construction plans (BCP). This technique helps designers balance the impact of bridge construction plans on project performance, traffic flow, and business activities. The model incorporates five major factors: safety, accessibility, carrying capacity, schedule performance, and budget performance (*El-Diarabi et al. 2001*). These factors were extracted through observation of actual construction projects and further validated by industry experts and application to new actual construction cases. Model factors are weighted by experts of the domain and are then used in an objective matrix. An example of such matrix can be seen in Figure 1.3.

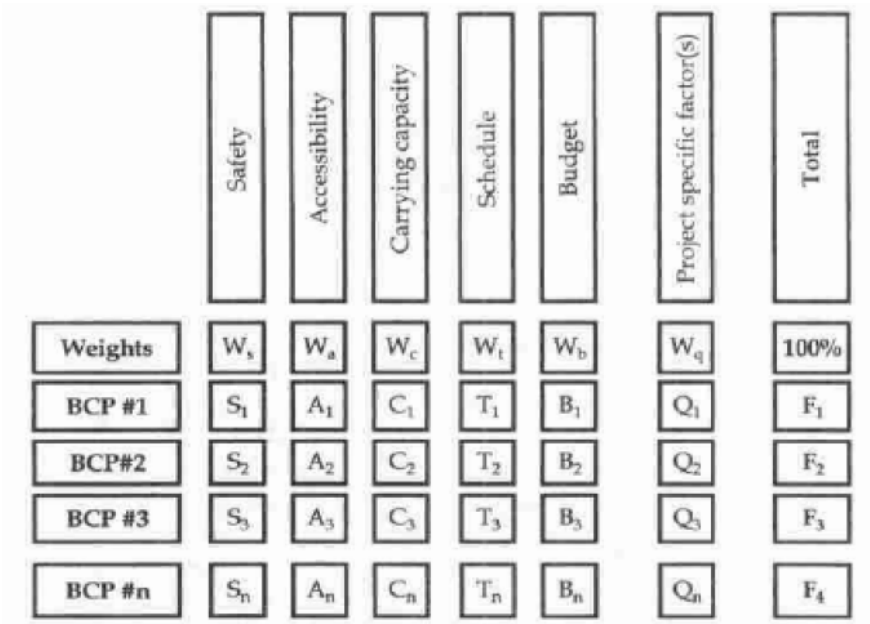


Figure 1.3: BCP Objective matrix (*El-Diarabi et al. 2001*)

Factors are scored on a scale of 1 to 10, and the final score for each plan is calculated through a formula summarized in Equation 1.1.

$$F_i = (W_s X S_i) + (W_a X A_i) - (W_c X C_i) + (W_t X T_i) - (W_b X B_i) - (W_q X Q) \quad \textbf{(1-1)}$$

The described methods have two major drawbacks. First, every project is unique and has its own specific requirements. Specific numerical values for the importance of various factors cannot be universally applied. Second, both methods are missing a systematic and justifiable method for criteria weighting. A third approach taken from the literature addressed these issues.

In the third approach, the decision making process is based on the Analytical Hierarchy Process (AHP). This approach provides the decision maker with a tool to evaluate various alternative construction strategies by considering both quantitative and qualitative criteria (*Arurkar 2005*). AHP quantifies not only the criteria, but also quantifies the qualitative trade-offs and relationship between the criteria using a hierarchy of criteria.

The method uses pair wise comparisons to compare the relative importance of each factor with other factors using both a numerical and verbal scale. Figure 1.4 shows the structure of the criteria breakdown in an AHP decision study. Since AHP is able to consider both tangible and intangible decision factors, it can be used as a powerful and reliable technique for ABC decision making.

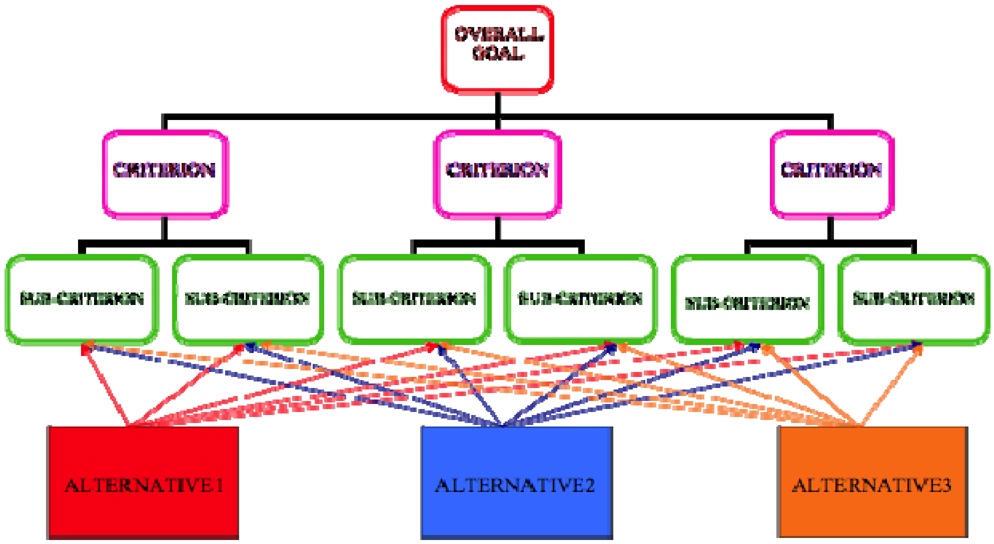


Figure 1.4: Schematic representation of decision hierarchy

1.2.2 Successful ABC Projects

A large number of successfully performed ABC projects were reported in the literature. More specifically, Table 1.1 lists documents that contained a considerable amount of information on successful projects.

Table 1.1: Outstanding Examples from the Literature about Successful Projects

1. Accelerated Bridge Construction Success Stories (*FHWA 2006*)
2. Final Report Highways for Life Report (*ODOT 2009*)
3. California and Washington strategic plans, UDOT white paper on benefits and costs of PBES (*UDOT 2008; WSDOT2009b*)
4. Scan reports from Europe and Japan introducing accelerated construction projects conducted using innovative accelerated technologies (*Ralls et al. 2005*)

1.2.2.1 ABC Maturity Level

Through the literature review, ABC maturity levels were also investigated. Primary goals and barriers identified for using ABC techniques based on a review of the literature are summarized in Table 1.2.

Table 1.2: Primary Goals and Barriers of ABC

Primary ABC Goals	Barriers to Using ABC
• Deliver projects earlier to traveling public • Reduce the impacts of on-site construction • ABC to become Standard Practice	• Traffic detour issues • Technical issues related to seismic design, structure durability and reliability • Poor communication and coordination between stakeholders • Lack of technology for rapid bridge construction and replacement technologies for extreme events • Development needed in design methodologies, contracting approaches, material supply chain management

There is a propensity from both community and industries involved in construction projects and federal organizations towards standardization of ABC. Community members want to deliver bridge construction projects quickly to reduce congestion and improve safety (*Ralls 2007*). September 11 and subsequent threats to U.S. transportation system emphasized the need to develop emergency response plans to quickly react to consequences of extreme events (*Bai and Burkett 2006*).

Federal organizations have also conducted several projects to develop, implement, and promote ABC. Because of the success of accelerated bridge construction projects to date, the FHWA has increased its support and provided resources to further advance the development of these systems into more conventional practice nationwide (*Ralls 2007*). The FHWA framework for prefabricated bridge elements and systems (PBES) decision-making is another outstanding effort to ensure cost-effective use of prefabricated bridges.

The literature also indicated recommendations from AASHTO and FHWA for updating highway emergency response plans for extreme events. It included recommendations from NCHRP for the design of bridges for extreme events (*Bai and Kim 2007*). The focus of recent national initiatives by AASHTO and FHWA was on newer, innovative prefabricated bridge elements and systems, e.g. bent caps, abutments, full-depth deck panels, and totally prefabricated superstructure and substructures (*Arurkar 2005*).

1.2.3 PBES Techniques and Innovations

Prefabricated bridge systems include superstructure systems (composite units, truss spans), substructure systems (abutments, caps/columns, piers) and totally prefabricated bridges. Using prefabricated bridge elements and systems has many advantages such as: (*FHWA 2007*)

- Reduced on-site construction time
- Minimized traffic impacts of bridge construction projects
- Increased construction work zone safety
- Less disruption to the environment
- Improved constructability
- Increased quality and lowers life cycle costs

Figure 1.5 shows a representation of various ABC techniques. This figure tries to categorize ABC techniques based on the available methods.

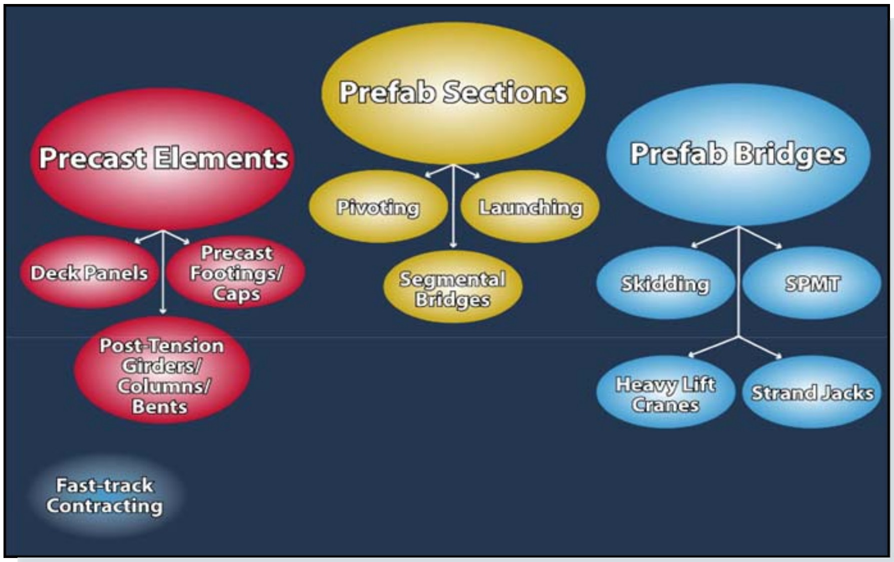


Figure 1.5: Representation of ABC techniques
(*Successful use of accelerated bridge construction techniques in UTAH, New Jersey DOT 2009*)

The literature also suggested the use of management techniques along with technical methods and practices to accelerate construction projects. The management practices taken from the literature were:

- Staged construction
- Changing normal operational procedures along with A+B contracting. A+B contracting is a method of rewarding a contractor for completing a project as quickly as possible. By providing a cost for each working day, the contract combines the cost to perform the work (A component) with the cost of the impact to the public (B component) to provide the lowest cost to the public.
- Changing normal operational procedures I/D (Incentive-Discentive) contracting.
- Lane Rentals
- New design techniques and materials

A summary of the construction project decision making processes currently in use for five of the states involved in this study (California, Oregon, Texas, Utah, Washington) and the Federal Highway Administration is provided in Table 1.3. The detailed decision-making models from these states and FWHA are included in Appendix C.

Table 1.3: Summary of the Construction Project Decision Making Processes

	Washington	California	Utah	Oregon	Texas	FHWA
Framework	Table	Table	Flowchart	Flowchart	Flowchart	Table & Flowchart
Analysis Type	Qualitative	Quantitative	Qualitative	Qualitative	Qualitative	Qualitative
# of Decision Criteria or Branches	21	20	13	8	9	8
Project Criteria						
ADT	+	+	+		+	+
Emergency Replacement	+	+		+	+	+
Safety	+	+	+		+	+
Evacuation Route	+	+	+		+	+
Construction Conflict	+			+		
Environmental Restrictions	+	+	+	+	+	+
Railroad	+	+	+	+		+
Project Critical Path	+	+			+	+
Weather Constraints	+	+	+			+
Detour	+		+	+	+	+
Lane Closure	+	+		+	+	+
Old Bridge	+			+		+
Bridge Life Cycle	+					
Material Availability			+			+

1.2.4 User Cost Estimation

Three categories of user costs are generally used in the literature for an economic analysis or lifecycle costs analysis. These include vehicle operational costs (VOC), delay costs, and crash costs or safety related costs. The logic behind user cost analysis is to assess the value of time lost in congestion and vehicle operating costs resulting from congestion.

A large amount of data on costs related to transportation delays was available in the literature. For example, since 2003, the Urban Planning Office has performed annual updates to the cost of delay values based on the prior year data such as ADT, travel cost, delay times, etc (*WSDOT 2009*a. Figure 1.6 shows an example of such data.

The data provided in these tables can be used in the estimation of vehicle operation costs, delay costs, and safety costs. An example of this estimation can be found in *'Assessing Cost of Travel Annual Update'* (*WSDOT 2009a*).

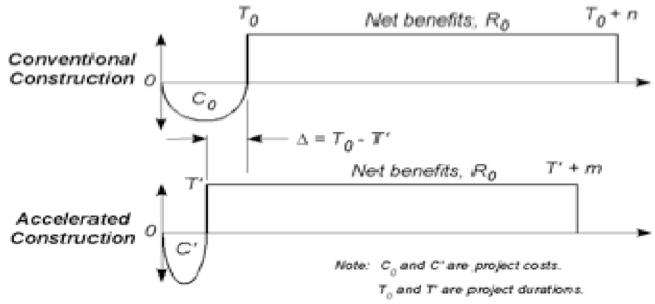
	$/mile	$/hour
Vehicle-Based		
Fuel cost (excluding taxes)	0.121	5.44
Fuel taxes	0.023	1.05
Engine oil change	0.012	0.53
Repair and maintenance	0.049	2.205
Tire cost	0.007	0.315
Tolls	0	0
Sub Total	**0.21**	**9.53**
Driver/Passenger-Based		
50% of average wage rate	0.25	11.19
Sub Total	**0.25**	**11.19**
Total Expense	**0.46**	**20.72**

Cost Category	Age (yrs)	Baseline Pavement Service Life (11 years)	As Built (PCfC) Pavement Service Life (20 years)
Preliminary Design and Engineering, Construction, Construction Engineering, and Incentives	0	$3,792,056	$5,161,128
Delay-Related User Costs		$2,064,185	$ 346,816
Crash-Related User Costs		$ 67,667	$ 0
Preventive Maintenance (MDOT Manual) 11.12 lane-mile @ $27,192 per lane-mile	5 (baseline) 6 (as-built)	$ 302,375	$ 302,375
Preventive Maintenance (MDOT Manual) 11.12 lane-mile @ $44,891 per lane-mile	9 (as-built)		$ 499,188
Reconstruction or HMA Overlay (Preliminary Design and Engineering, Construction [Roadway Pay Item, Mobilization, Traffic Control, Contingencies], Construction Engineering)	11 (baseline)	$ 102,043 $2,551,065 $ 127,553 $ 178,575 $ 76,532 $ 165,819	
Delay-Related User Costs		$2,064,185	
Crash-Related User Costs		$ 67,667	
Salvage Value (2 of 11 years remaining life for baseline pavement)	20	- $ 582,107	$ 0
Total Actual Costs		**$ 10,977,615**	**$ 6,309,507**
Net Present Value of All Costs		**$ 9,679,453**	**$ 6,116,503**

Figure 1.6: Cost of Delay Values

Many agencies are investigating economic tools such as life-cycle cost analysis (LCCA) to help them choose the most cost-effective alternatives and communicate the value of those choices to the public. To compare the alternatives, future expenditures of the project and the benefits to the public after completion are analyzed and compared (*Trejo and Reinschmidt 2005*).

Figure 1.7 compares the net flow of initial costs and future benefits for a project using both conventional and accelerated methods. The project consists of an initial investment cost, followed by operational costs. Benefits of the project are shown as positive values that start after the completion of the project.



$$NPV = Initial\ Cost + \sum Future\ Cost * \left[\frac{1}{(1+i)^t} \right]$$

Figure 1.7: Economic Analysis of Conventional and Accelerated Construction Timelines
(*Trejo and Reinschmidt, 2005*)

During the literature review, the research team also tried to identify the existing tools and software used for ABC analysis. To promote the development and deployment of applied research in roadway construction, the Federal Lands Highway (FLH) initiated the development of FLH-QuickZone to help estimate roadway construction soft costs. QuickZone is a Microsoft Excel based program that can be used to model various work zone configurations to estimate economic impacts of roadway construction. The FLH-QuickZone was tested and prototyped in six FLH construction projects (*Hardy et al. 2007*).

1.2.5 Bridge Construction Index

Another method used to categorize ABC projects is the Bridge Construction Impact (BCI) index. Figure 1.8 shows the criteria and measures used in a BCI calculation.

- Facility Category
  - I. Residential community traffic
  - II. Local streets (business and residential)
  - III. State routes, major city arteries, or minor utilities (water channel etc).
  - IV. Interstate or State Highways
  - V. Essential artery, major landmark facilities, utilities, or natural hazard (waterways, swamp lands, etc.)
- Mission Impact Type
  - Capacity Improvement/Restoration- Improve or restore capacity to relief existing traffic congestion due to an event, incident, or demand growth.

    C1-Lanes and shoulder widen, soundwall addition, and add/restore 1-30% of total lanes and or shoulder widen.

    C2-Add/restore 31-66% of total lanes + shoulder widen

    C3-Add/restore 67-100% of total lanes + shoulder widen
- Traffic Impact Intensity
  - Traffic Delay-Due to temporary construction-related operations on traffic congestion (number of days).

    T1-Reduce widths of lanes and shoulder, closure of 1-30% of total lanes and/or shoulder or lane realignment.

    T2-Closure of 31-66% of total lanes + shoulder.

    T3-Closure of 67%-100% of total lanes + shoulder
- Environmental Impact Levels-Due to temporary construction-related operations (number of days).

  E1-None to Mild

  E2-Moderate

  E3-Severe
- Impact Measures: in XX of YY-hour days (Z)

  XX=Number of days; YY=Number of hours; Z=Type of hours:

  PK=Peak, commuting and heavy traveled hours.

  OP-Off-Peak, non-commuting and moderate traveled hours.

  NS=Non-standard, light-traveled hours (e.g. midnight)

Figure 1.8: Bridge Construction Impact Criteria
(*ABC- Advisory Council 2008*)

2.0 TASK 2

The focus of Task 2 was to analyze a number of ABC projects completed under the Highway for Life (HfL) program. To help perform this analysis, a data collection template was developed using Microsoft Excel and Visio. The first version of the data collection template was built as an Excel spreadsheet, in which data entities were represented in columns and projects were represented in rows. Figure 2.1 provides an illustration of this template.

Category	Variable	1	2
General Bridge Information	Age	53	80
	Bridge ADT	25000	680
	Bridge Location	State: VA, Gainesville ,Prince William County	Addison, Washington County, Maine
	Environmental Characterstics	Adjacent to historic properties: Buckland Historic District	School, cumercial trucks, emergency vehicles, sensitive water courses that restrict the construction footprints and
	Existing Structure Details	3 spans reinforced concrete T-beam 130 ft, Two Lane	Single span precast/prestressed concrete with integral abutments, 200 ft roadway, Width: 28 ft
	Contract type	A+(B*C)	
	Detour Length	11mi	16mi
	Detour Delay	9461 v-h	
	New Structure Details	Width: 38.5 ft	Width: 28 ft, 46 ft single span
	Conventional Construction Cost (Estimated)	$3,346,300	
	Conventional Construction Time (Estimated)	100 Days	270 Days

Figure 2.1: Data Collection Template - Spreadsheet Format

The second version of the data collection template was developed using a flowchart representation. The flowchart version provided a clearer representation of the data elements and relationship between data elements than the Excel spreadsheet representation. This template was developed using Visio, and an illustration of this template is provided in Figure 2.2.

Data from eight different HfL projects were collected and compiled using both of these templates. The data collection templates were presented in the April 2010 TAC meeting. The templates were reviewed and approved by the TAC team.

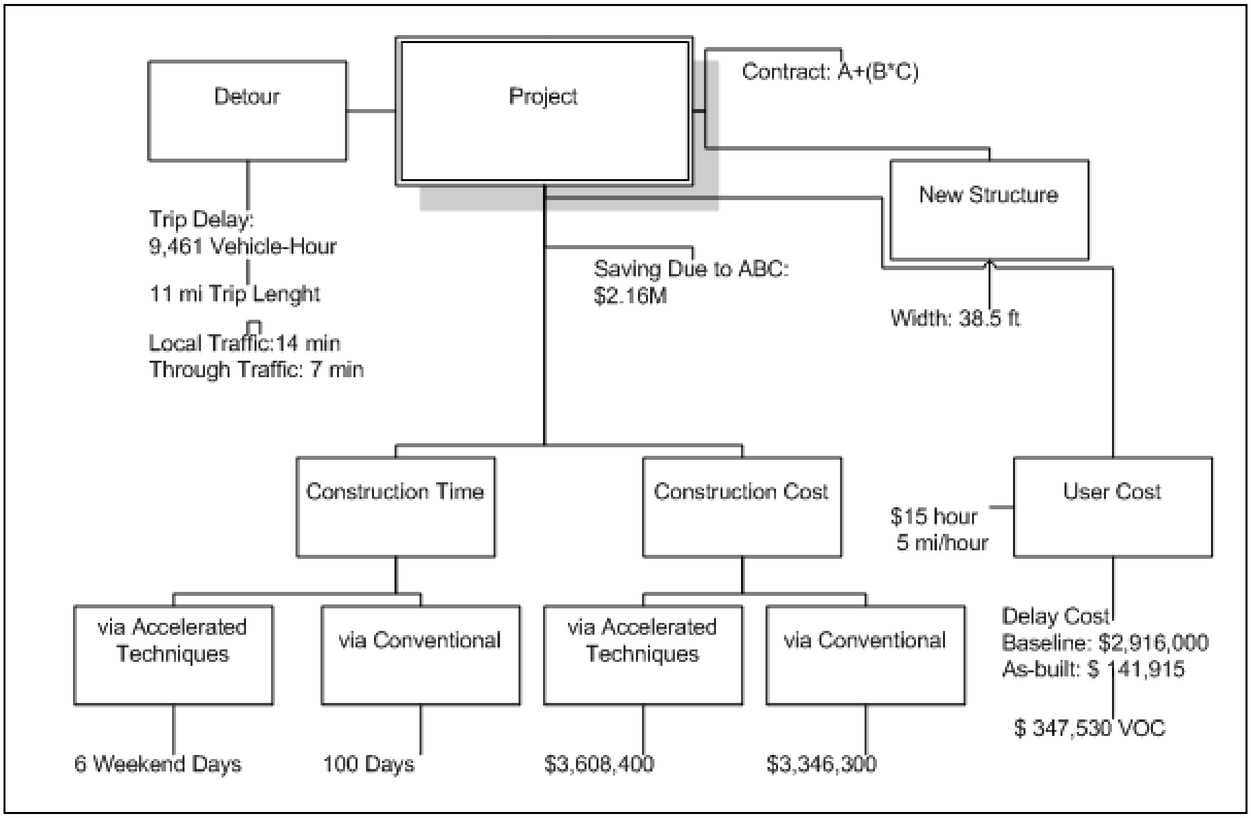


Figure 2.2: Data Collection Template - Flowchart Version

3.0 TASK 3

At the April 2010 face-to-face meeting with the TAC team, held in Portland, OR a summary of Task 1 and Task 2 results was presented. New TAC members from Montana and Texas were introduced. The research team used the meeting to get input from the TAC team needed to initiate Task 3. In a series of brainstorming sessions, TAC members discussed the criteria currently considered by their states in the decision-making process for determining if conventional or ABC techniques would be used. The focus of the brainstorming was to identify a complete list of factors affecting decisions on the type of construction techniques used for a bridge replacement/rehabilitation project. The outcome of this effort was the creation of a comprehensive list of factors that enter into the decision-making process. Preliminary categories for each decision criteria were also identified. This list along with definitions is provided in Appendix D.

From the brainstorming work of the TAC team as well as the review of the literature completed as part of Task 1, it was determined that bridge construction decisions are based on both quantitative and qualitative data. In addition, it was determined that some of the factors that enter into the decision-making process are difficult to fully quantify at the point in which decisions must be made. Having these diverse types of decision criteria makes finding a suitable technique difficult, since many decision-making techniques are not able to integrate both qualitative and quantitative criteria simultaneously. After a comprehensive literature review, the research team recommended that a tool called Analytical Hierarchy Process (AHP) be considered for this project. AHP is a technique that aids decision makers in prioritizing multiple criteria, and the outcome from an AHP analysis is a ranking of various design alternatives. Overall, AHP is well-suited for multi-criteria decision-making. AHP was introduced by Saaty (*1977*), and its application in other domains is well-documented in the literature.

AHP is a decision support tool that can be applied to complex decisions. AHP uses a multi-level hierarchical structure of objectives, criteria, sub criteria, and alternatives. The pertinent data to conduct an AHP analysis are created using a set of pairwise comparisons. These pairwise comparisons are used to calculate the importance weight for each decision criteria and to evaluate the relative priority of each alternative in terms of each decision criterion. The pairwise comparisons are stored in a series of comparison matrices.

Despite the introduction of the AHP in the civil/structural engineering literature, the process has not been widely used in practice and may be unfamiliar to transportation personnel. The underlying hierarchy model uses pairwise comparisons of different criteria and a process by which these are combined to create a final recommendation. If the model or pairwise comparisons do not accurately reflect the criteria, this will be directly reflected in the results and inconsistencies in the comparisons will make the results unreliable.

These comparison matrices are briefly explained in the following parts. The criteria list developed by the TAC members for this study was converted into a hierarchy. The hierarchy developed for this research had three different levels (see Figure 3.1). The three levels produced a “four-level” (including the alternatives) AHP problem.

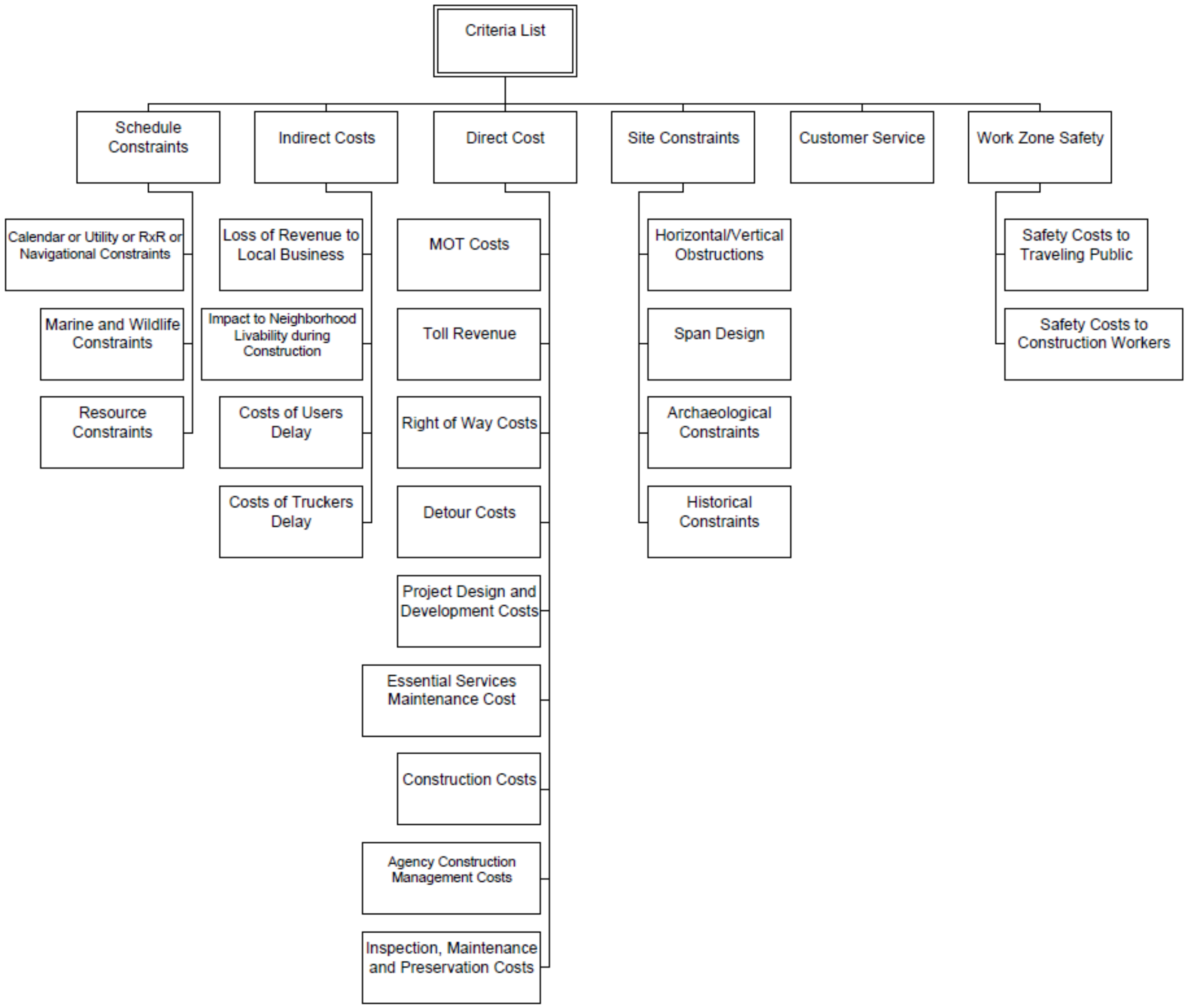


Figure 3.1: Early version of Decision Criteria Hierarchy

It is important to note that the hierarchy and the list of criteria were not finalized at this point, and it was expected that additional modifications to both the hierarchy and criteria would occur as Task 3 work continued. In particular, the research team was working with TAC team members and other domain experts to ensure that the criteria list contained all the necessary elements that should be considered in a bridge design selection problem and that the hierarchy had properly categorized each criterion.

The hierarchy and criteria were incorporated into a primary survey form that could be used to collect pairwise comparisons to analyze a bridge project. The survey contained all pairwise comparisons associated with the first version of the decision hierarchy. The survey format was designed to enable bridge designers and project personnel to be able to complete the required comparisons without a deep knowledge of AHP or the mathematical procedures associated with AHP. The preliminary version of the survey list is included in Appendix E.

To check the robustness of the criteria and to provide an illustrative test of how the AHP tool could be used for a bridge construction project, a test case was completed. Reports were collected for a number of completed bridge construction or rehabilitation projects under the Highway for Life (HfL) program. Figure 3.2 illustrates an example of the output of an AHP analysis completed for one of these bridge construction projects, which occurred in Gainesville, Prince William County, VA. The data provided in the HfL report was used to perform the required pairwise comparisons. Although the comparisons were performed by a member of the research team, who was not an expert in bridge construction, the results were reasonable. In this example, the results of the AHP analysis suggested that the ABC construction alternative was preferable over conventional construction methods. Based on the results, “Safety” and “Site Constraints” were the decision criteria that had the greatest contribution to this recommendation.

Figure 3.2: Example AHP analysis for Gainesville project

The research team performed a series of similar tests on completed and in-process bridge construction projects. Because not all of the necessary data for the required pairwise comparisons were available in the written HfL reports, the research team contacted personnel at the appropriate DOT for input information. Data required to perform pairwise comparisons for these additional projects were collected through interviews. During the next steps, additional interviews were also planned and conducted with personnel from other TAC member DOTs.

3.1. ANALYTICAL HIERARCHY PROCESS

Analytical Hierarchy Process (AHP) is a decision making technique that is designed to cope with both the rational and the intuitive to select the best option from a set of alternatives evaluated with respect to several criteria (*Saaty and Vargas 2001*). In this technique, the decision maker performs simple pairwise comparison judgments that are then used to develop overall priorities for ranking the alternatives.

The simplest form that AHP can be used to construct a decision making problem is a hierarchy consisting of three levels: the overall goal of the decision, the criteria by which the alternatives will be evaluated, and the available alternatives (See Figure 3.3). This hierarchy schema helps the decision maker in the decomposition of complex systems. One organizes the factors affecting the decision (i.e. criteria and sub-criteria) in gradual steps from the general, in the upper levels of the hierarchy, to the particular, in the lower levels. This structure makes it possible to judge the importance of the elements in a specific level with respect to some or all the elements in the adjacent level above.

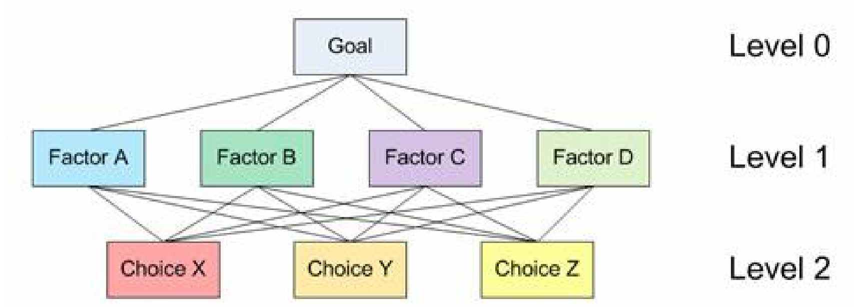


Figure 3.3: A schematic three-level decision making hierarchy

When hierarchies are constructed, enough relevant detail must be included to present the problem as thoroughly as possible, but not so detailed to lose sensitivity of change in the elements. When constructing a hierarchy, a number of important issues such as the environment surrounding the problem, attributes contributing to the solution, and participants associated with the problem must be considered. The elements included in the hierarchy must be homogenous at each level and capture the same degree of specificity. For example, if a Level 1 criterion is safety, then a second Level 1 criterion might be cost. An inappropriate Level 1 criterion would be construction cost because it is more specific than cost and would be inconsistent with the Level 1 criterion of safety. However, construction cost would be an appropriate Level 2 criterion under the cost criterion within the hierarchy. Similarly, an appropriate Level 2 criterion under the safety criterion would be worker safety. The hierarchy does not need to be complete; that is, an element in a given level does not need to function as a criterion for all the elements in the level below. Furthermore, a decision maker can insert or eliminate levels and elements as necessary to clarify the pairwise comparison or to sharpen the focus on one or more parts of the system. Sometimes the less important elements can be dropped from further consideration if the judgments and prioritization show a relatively small impact on the overall objective.

3.1.1. Procedure of the AHP

The AHP technique can be used to extract ratio scales from both discrete and continuous pairwise comparisons in multilevel hierarchy structures. These comparisons can be performed from actual measurements or from a fundamental scale that represents the relative strength of preferences and feelings. The AHP takes several factors into consideration simultaneously, allowing for dependence and feedback and making numerical tradeoffs to arrive at a synthesis or conclusion. The AHP can be used to establish measures in both physical (tangibles) and social (intangibles) domains.

The first step in using the AHP to model a problem is to develop a hierarchy or a network representation of that problem. In the next step, a series of pairwise comparisons must be carried out to establish relations within the structure. These comparisons lead to a set of reciprocal matrices (See Figure 3.4). More information about the characteristics of these matrices can be found in (*Basak and Saaty 1993*). Pairwise comparisons in the AHP are performed with homogenous elements. The fundamental scale of values to represent the intensities of judgments is shown in Table 3.1. This linear scale is a one-to-one mapping between the set of discrete linguistic choices available to the decision maker and a discrete set of numbers that represent the importance or weight of the previous choices (*Triantaphyllou 2000*). This scale has been validated for effectiveness, not only in many applications by a number of people, but also through theoretical justification of what scale one must use in the comparison of homogeneous elements (*Saaty and Vargas 2001*).

	Loss of Revenue to Local Business	Impact to Neighborhood Livability during Construction	Costs of Users Delay	Costs of Truckers Delay
Loss of Revenue to Local Business	1.00	0.14	0.20	0.25
Impact to Neighborhood Livability during Construction	7.00	1.00	3.00	3.00
Costs of Users Delay	5.00	0.33	1.00	3.00
Costs of Truckers Delay	4.00	0.33	0.33	1.00

Figure 3.4: Comparison Matrix

Table 3.1: The Fundamental Scale of the AHP Pairwise Comparison

The Fundamental Scale for Pairwise Comparisons		
Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one element over another
5	Strong importance	Experience and judgment strongly favor one element over another
7	Very strong importance	One element is favored very strongly over another, its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one element over another is of highest possible order of affirmation
Intensities of 2, 4, 6, and 8 can be used to express intermediate values. Intensities 1.1, 1.2. 1.3, etc. can be used for elements that are very close in importance.		

In 1846 Weber (as reported in [*Saaty 1980*]) stated his law regarding a stimulus of measurable magnitude. According to his psychological theory a change in sensation is noticed if the stimulus is increased by a constant percentage of the stimulus itself. That is, people are not able to make choices from an infinite set. For example, people cannot distinguish between two very close values of importance, say 3.00 and 3.02 (*Miller 1956*). This is the main reasoning used by Saaty to establish 9 as the upper limit of his scale, 1 as the lower limit and a unit difference between successive scale values (*Saaty and Vargas 2001*).

Synthesis is obtained by a process of weighting and adding down the hierarchy leading to a multilinear form. In the disruptive mode of the AHP, the principal eigenvector is normalized to yield a unique estimate of a ratio scale underlying the judgments. This vector shows relative weights among the elements that are compared. Aside from the relative weights, one should also check the consistency of the pairwise comparisons. A comparison matrix 'A' is said to be consistent if

$$a_{ij}.a_{jk} = a_{ik} \quad \textbf{(4-1)}$$

for all i, j, and k. However, the consistency shall not be forced. Since we are dealing with human judgment, too much consistency is undesirable. Saaty proved that for a consistent reciprocal matrix, the largest eigenvalue is equal to the size of comparison matrix, or

$$\lambda_{max} = n \quad \textbf{(4-2)}$$

Measure of consistency, called the Consistency Index, was also defined by Saaty (1980) as the deviation or degree of consistency using the following formula:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad \textbf{(4-3)}$$

The Consistency Index is compared to a Random Index (RI) and is used to calculate the Consistency Ratio (CR). RI are obtained by randomly generating the reciprocal matrices using the fundamental scale and getting the random consistency index to see if it is about 10% or less. The average random consistency index of sample size 500 matrices is shown in the Table 3.2.

Table 3.2: Average Random CIs of Sample Size 500

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$CR = \frac{CI}{RI} \quad \textbf{(4-4)}$$

If the value of the Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, the subjective judgment needs to be revised.

4.0 USING AHP FOR DECISION MAKING

A decision making software tool for determining whether or not to use ABC techniques was created based on the AHP process. This tool will help decision makers in early stages of the design process. In this chapter, an introduction of the "ABC AHP Decision" tool developed for this research, along with some of the key software features are summarized.

In parallel to the software development effort, the research team collected data on a series of completed or under-construction bridge projects in Oregon. The data were collected through interviews with ODOT experts. The survey form presented in the previous chapter was used for this task. The survey and the software both used the fundamental AHP scale. This survey scale was based on previous research and was well-developed, tested, and validated (*Saaty 1990*). The survey form contained a series of pairwise comparisons between criteria located at multiple levels of a decision hierarchy.

The data collection and software development processes were conducted under the supervision of the TAC team. The researchers provided the team with detailed updates on the progress through sharing report documents and two teleconferences. In the last teleconference, held on October 18, 2010 the researchers introduced and demonstrated the ABC AHP Decision tool for the first time. The team received positive feedback on the overall tool performance and its user interface. The development process proceeded to its final steps and the research team managed to test more real-world construction projects using the software tool.

4.1. REVIEW OF OREGON PROJECTS AHP ANALYSES

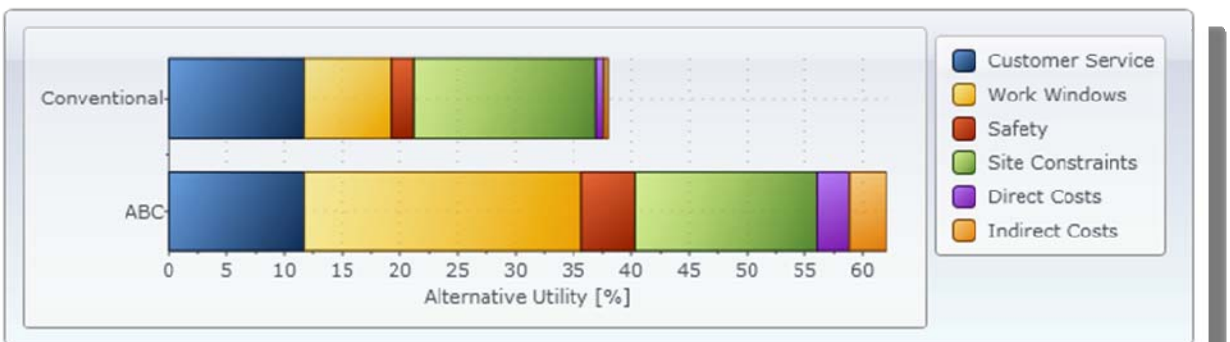
During Task 3, a number of bridge construction projects were reviewed. The purpose of this study was to evaluate these project cases by considering different conventional and accelerated construction alternatives using AHP techniques. These studies helped the research team to first validate the AHP model developed for this project and also to test the decision making software tool. In this section, a summary of the analyses conducted are presented.

It needs to be mentioned that the graphical results for the first two projects, Elk Creek and Pistol River Bridge, are the outcomes of a commercially available AHP software package, "Make It Rational." At this point of the project, the decision making software had not been fully developed; therefore, to test the validity of the AHP model, the research team used this software package.

4.1.1 Elk Creek Project

The Elk Creek project was completed by Oregon Department of Transportation. As a result, the research team was able to have a face-to-face meeting with an expert who worked on this project. The input data for the AHP analysis was collected through an interview session using the developed survey. The interview session showed that the survey form worked very well when the expert has detailed knowledge of the project under the study. This initial test of the survey also helped identify some modifications to the data collection processes discussed next

The initial analysis of the data showed some inconsistency with pairwise comparisons in a number of hierarchy nodes. Inconsistency can affect the reliability of the outcomes. The research team believed that the inconsistency issue was caused by extreme evaluation of criteria (i.e. many criteria were evaluated as 9 times more preferable). The major reason for the occurrence of this inconsistency was the unfamiliarity of the interviewee with the AHP rating scale, which could be resolved by providing training or definitions of the rating scale. Figure 4.1 shows the overall results of the AHP analysis for the Elk Creek project. The output suggested that an ABC approach was preferable over a conventional approach. The results showed that the criterion “Work Windows”(the name of this criterion was later changed to “Schedule Constraints”), was the largest contributor to this result (Figure 4.2). This finding was also in agreement with the interviewee’s overview of the Elk Creek project, which was discussed prior to completing the survey.



Alternative	Total	Customer_Service	Work_Windows	Safety	Site_Constraints	Direct_Costs	Indirect_Costs
ABC	62.050	11.730	23.970	4.640	15.730	2.830	3.150
Conventional	37.950	11.730	7.480	1.990	15.730	0.670	0.350

Figure 4.1: AHP analysis result for the Elk Creek project

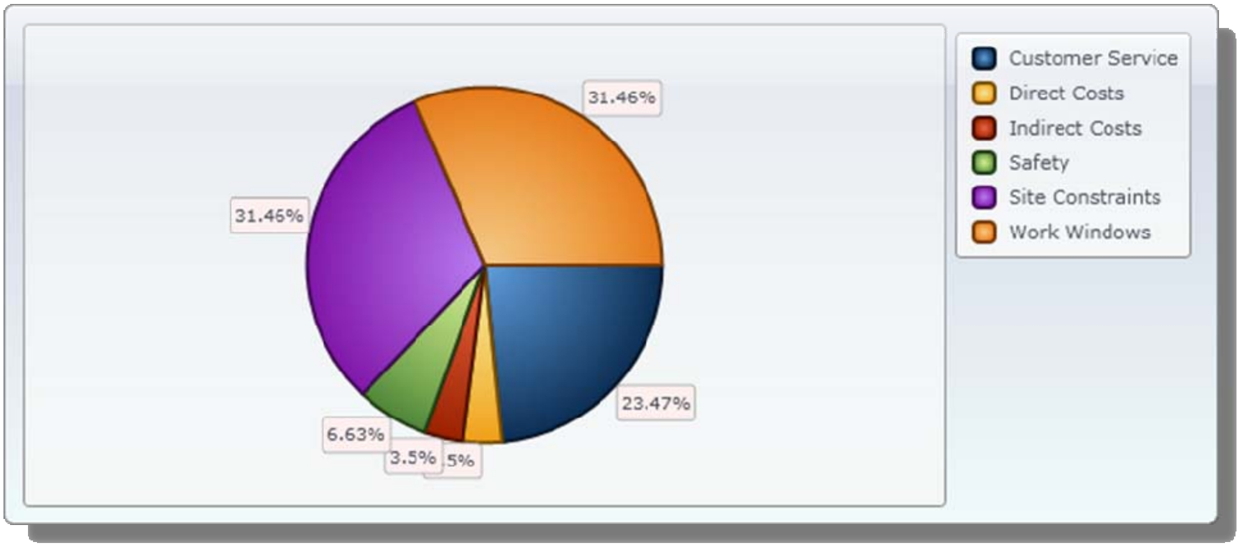


Figure 4.2: Criteria weights for the Elk Creek project

4.1.2 Pistol River Bridge Project

The Pistol River Bridge was constructed in 1961. At early stages of the project, decision makers planned for a rehabilitation project. However, due to the severe deterioration of the bridge, the plan was modified to undertake a bridge replacement project. The length of the replacement bridge was 1000 ft. The required data for this analysis was provided by a Senior Bridge Designer.

In this analysis, the ABC alternative was compared with two different conventional alternatives. The first alternative was a conventional bridge using a detour to maintain traffic. The second alternative consisted of a “realignment” step, which would allow a new bridge to be built beside the old bridge. The old bridge would be used for traffic during construction. The results of the analysis showed that in the first scenario, the utility values for the two alternatives were very close to each other, with only a slight (6%) preference for ABC (Figures 4.3 and 4.4). However, in the second scenario, the realignment alternative was much more preferable than the ABC alternative (Figures 4.5 and 4.6).

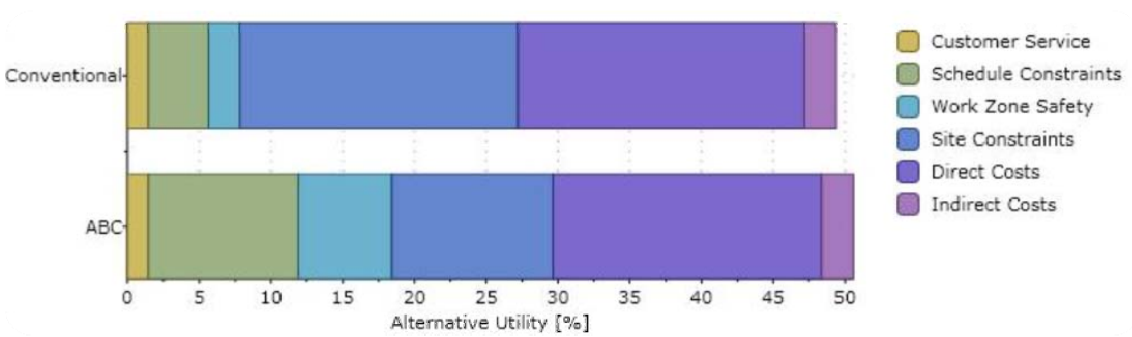


Figure 4.3: AHP analysis result for the Pistol River Bridge project (first scenario)

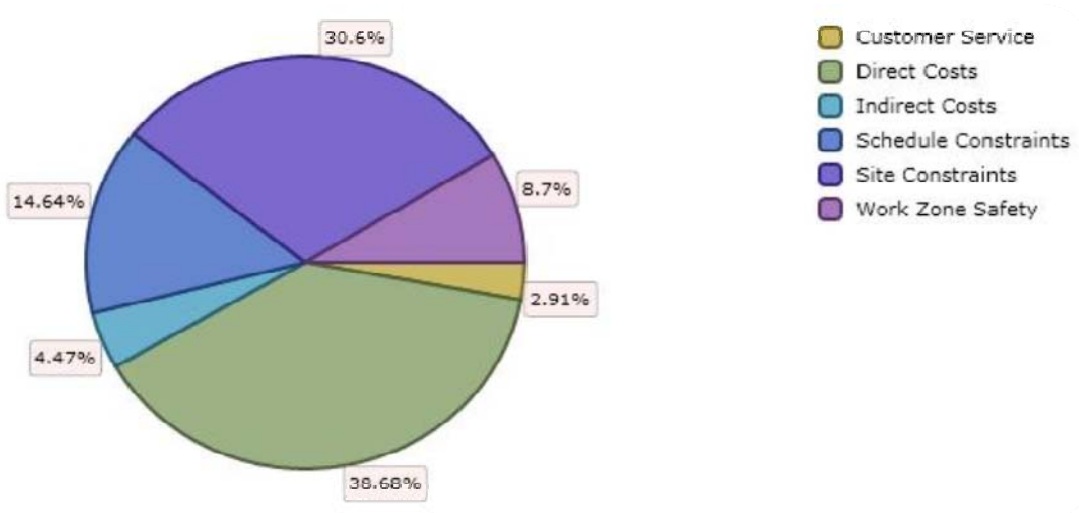


Figure 4.4: Criteria weights for the Pistol River Bridge project (first scenario)

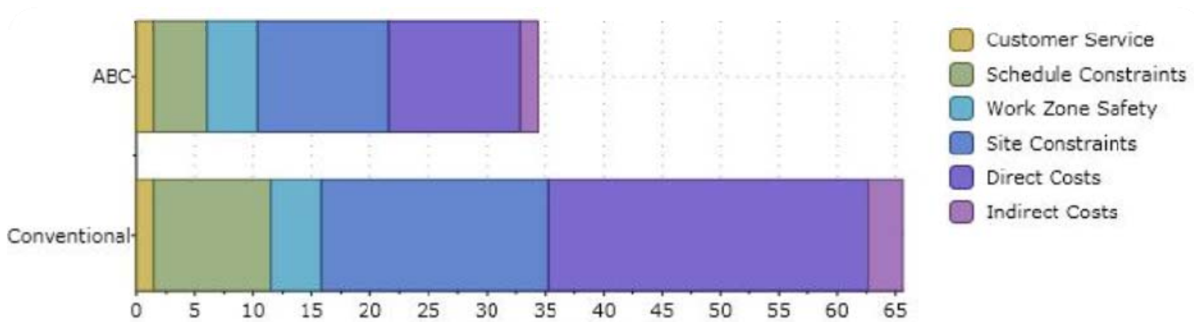


Figure 4.5: AHP analysis result for the Pistol River Bridge project (second scenario)

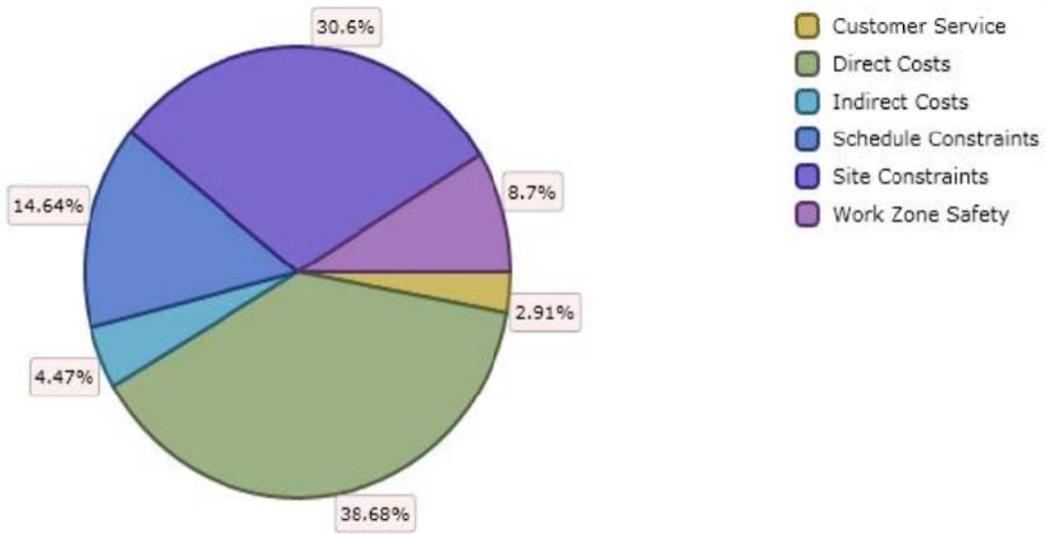


Figure 4.6: Criteria weights for the Pistol River Bridge project (second scenario)

4.1.3 Millport Slough Project

The required data for this analysis was provided by a project engineer and a project manager from Oregon Department of Transportation. The project was started in 2004 and the construction was not completed at the time of the analysis.

Based on the generated output from the interview with the project engineer, the Conventional alternative was preferred over the ABC alternative. The existing 2-lane structure was used to carry traffic while a staged first-half of the new 4-lane structure was being constructed. Traffic was then shifted to the new partially completed bridge before the contractor demolished the existing structure to finish the second half. This staging and use of the existing structure as a detour reduced the traffic interruption and neutralized the benefits of ABC. The calculated utilities for the ABC and Conventional alternatives were 0.473 and 0.527, respectively (Figure 4.7).

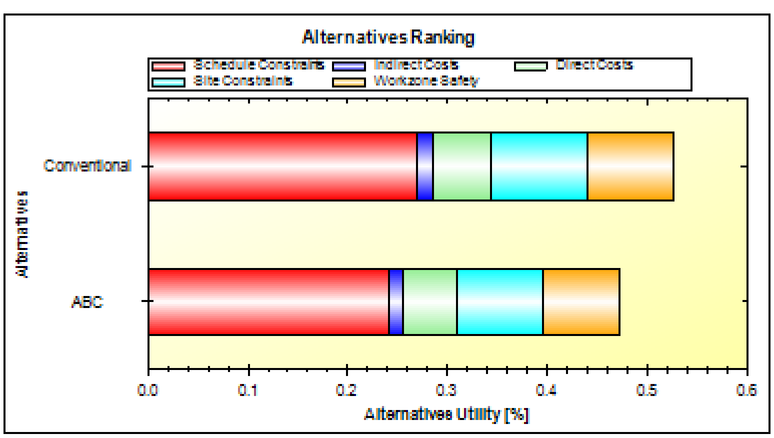


Figure 4.7: AHP analysis result for the Millport Slough project (first dataset)

Figure 4.8 presents the high-level criteria weights for the Millport Slough project. According to the results, “Schedule Constraints” and “Site Constraints” had the greatest impact on the project.

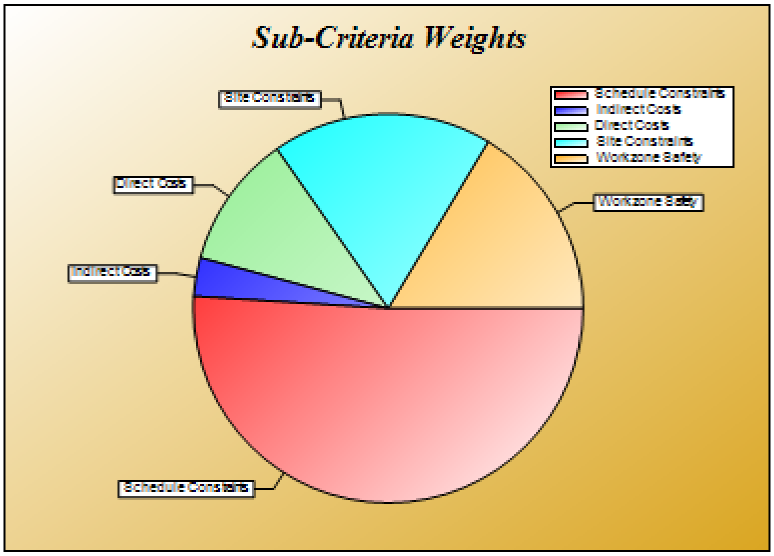


Figure 4.8: Criteria weights for the Millport Slough project (first dataset)

Based on the output generated from the second interview with the project manager, the Conventional alternative was preferred over the ABC alternative. The calculated utilities for the ABC and Conventional alternatives were 0.471 and 0.529, respectively (see Figure 4.9).

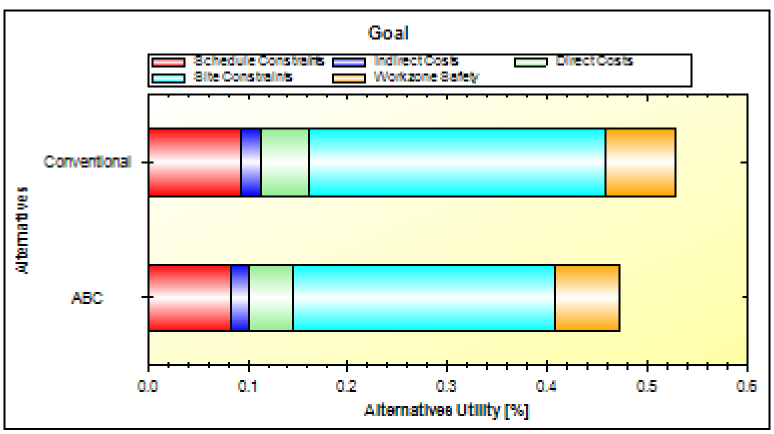


Figure 4.9: AHP analysis result for the Millport Slough project (second dataset)

Figure 4.10 presents the high-level criteria weights for the Millport Slough project. According to the results, “Site Constraints” and “Schedule Constraints” had the greatest impact on the project.

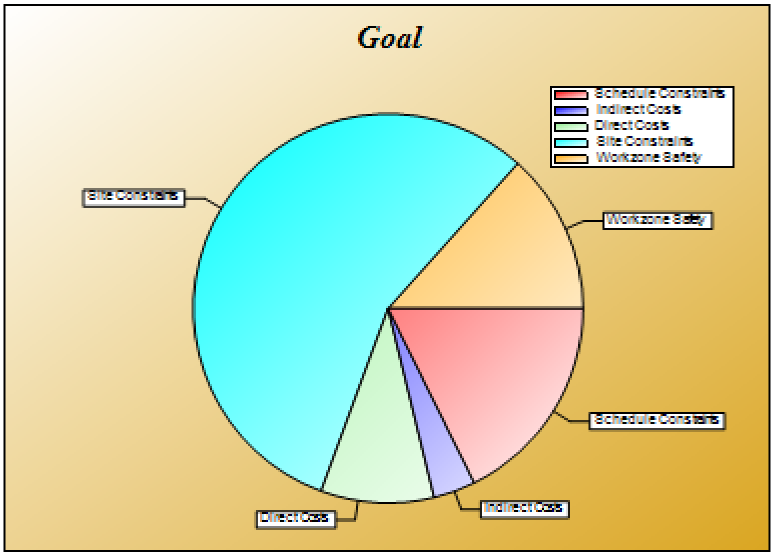


Figure 4.10: Criteria weights for the Millport Slough project (second dataset)

4.2. CUSTOMIZED ABC AHP DECISION TOOL DEVELOPMENT

In this section, a summary of the developed tool is presented. The Oregon State University ABC AHP Decision tool was developed using Microsoft Visual Studio .NET as a stand-alone application. The software was fully tested on all currently-supported Windows versions (i.e. MS Windows XP, Vista, and Seven). The software incorporates the most advanced software development concepts such as modular and object oriented design. As a result, the software has a high level of flexibility in addressing the user’s needs and future expansions. Figure 4.11 shows a screen shot from the primary version of the application’s graphical user interface (GUI).

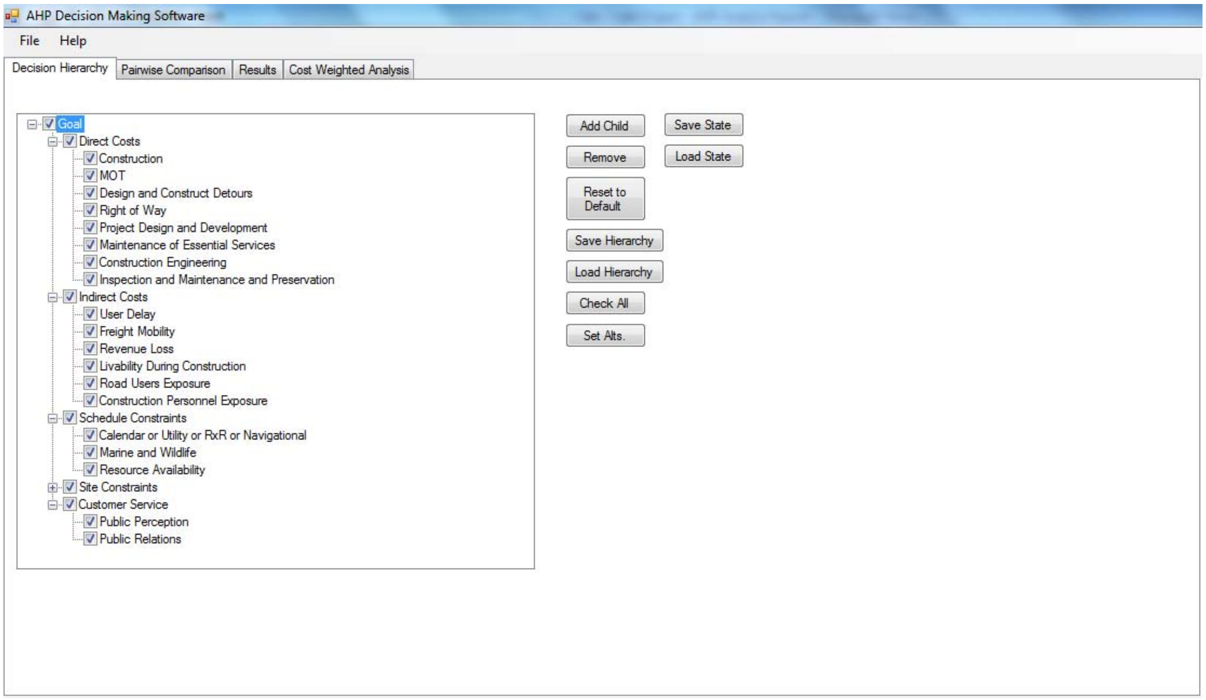


Figure 4.11: Decision Making Software Graphical User Interface (GUI)

The decision making software divides the overall AHP process into four steps using a tabular design. The first tab is associated with all tasks related to constructing a decision hierarchy. In this tab, the user has access to all necessary functions to support loading, saving, and modifying a decision model. The user has an option to disable a decision category either temporarily or permanently for every model. The second tab (see Figure 4.12) is associated with conducting the pairwise comparison process. The user can save the state of a study at any time and later return to that specific position without losing any data. After finishing all the pairwise comparisons, the user can review the AHP results in the third tab (Figure 4.13). For each node existing in the decision model, the tool will generate a set of two plots: a bar chart indicating the utility levels of the alternatives and a pie chart showing the weights for sub-categories. The last tab provides the user with the capability to complete an additional benefit-cost analysis (Figure 4.14). Although costs would typically be included in the hierarchy structure, in some cases, costs might be considered after other benefits of various alternatives have been evaluated. Using the cost weighted analysis feature when the cost criteria are included in the hierarchy will create a biased result. The cost weighted analysis tab must be used only after all cost criteria have been eliminated from the decision model constructed using the first tab. After completing the AHP process, the user can proceed to the cost weighted analysis tab.

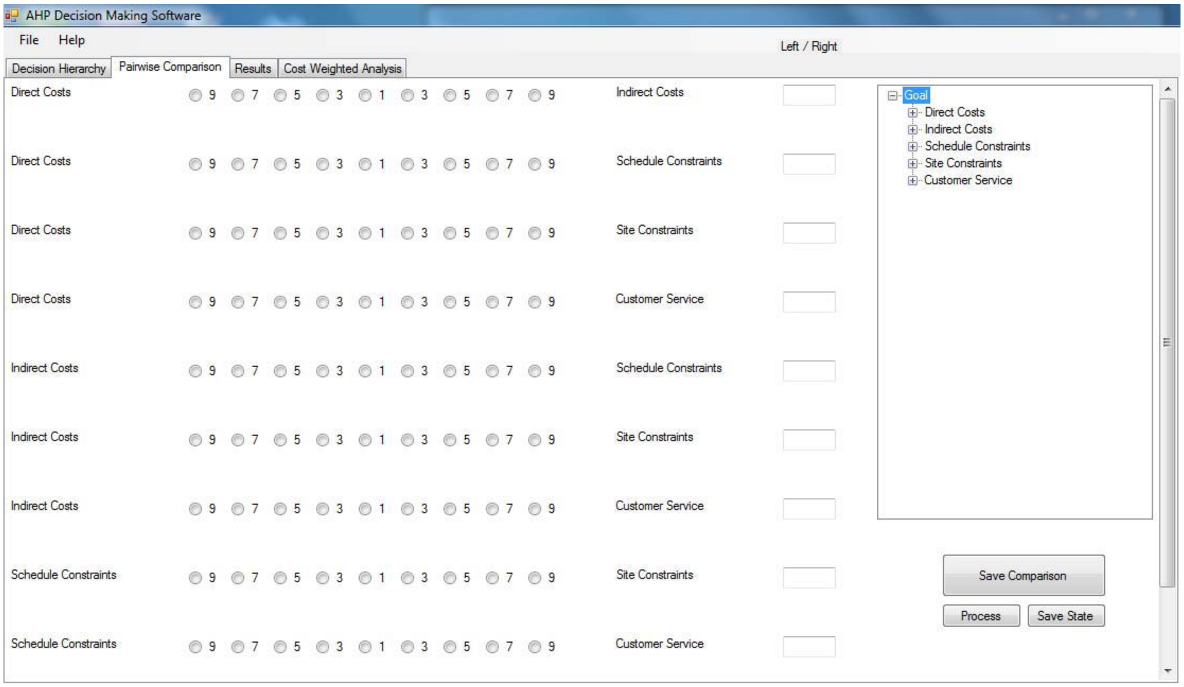


Figure 4.12: Pairwise Comparison tab

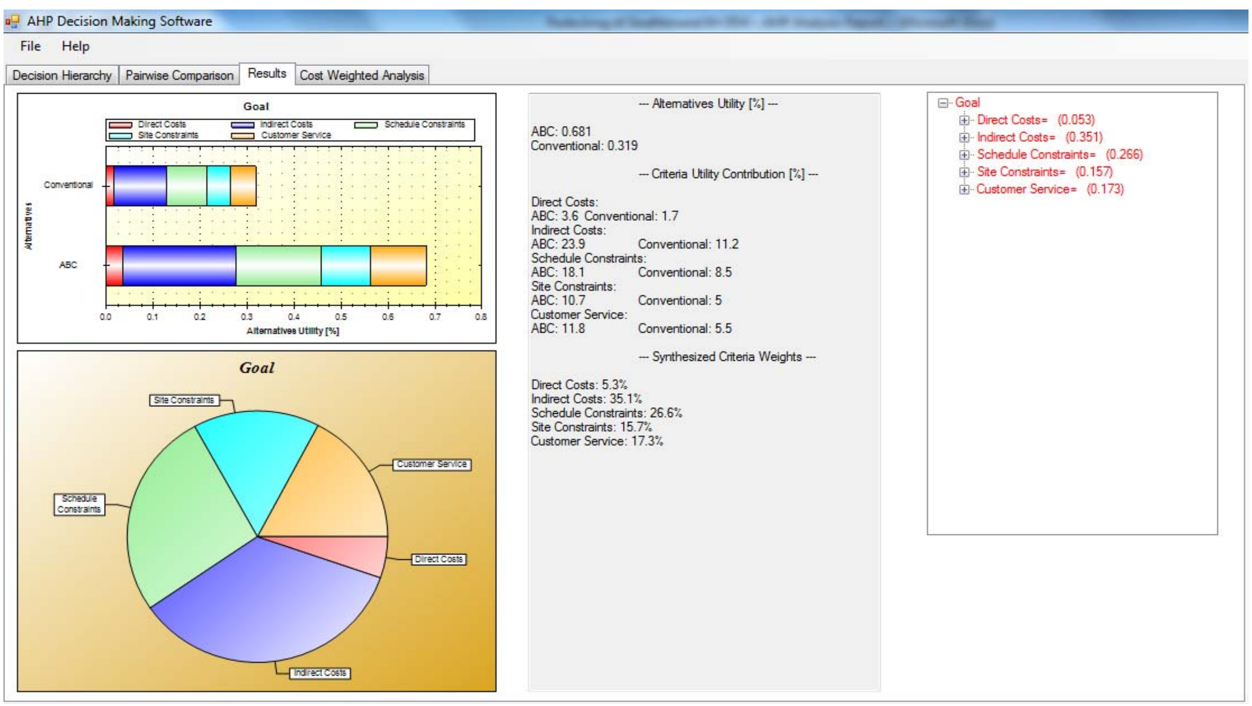


Figure 4.13: Results tab

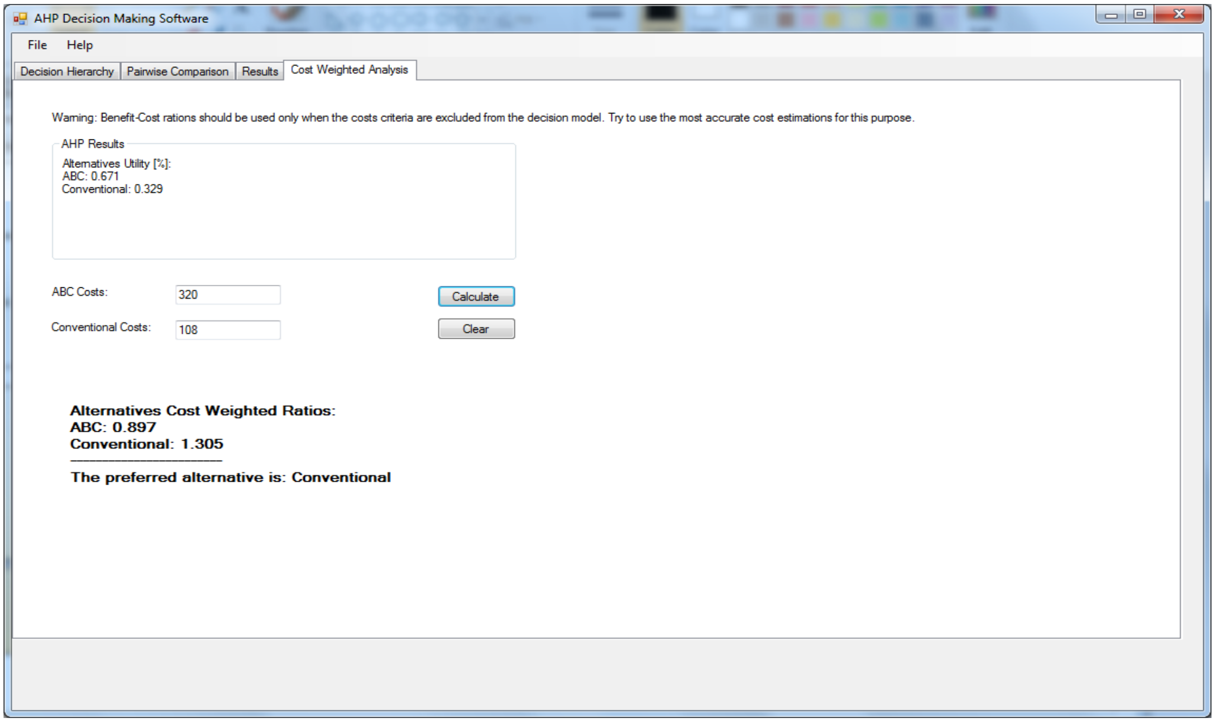


Figure 4.14: Cost Weighted Analysis tab

4.3. DECISION CRITERIA DEFINITIONS

The table provided in this section contains definitions for all criteria incorporated into the final version of the decision model. This definition list will enable users to understand the decision hierarchy and provide consistency between users when completing the pairwise comparison process. The definitions were developed under the supervision of the TAC team.

Table 4.1: Decision Criteria Definitions

Criteria	Sub criteria	Definition
Direct Costs	**Maintenance of Traffic (MOT) Costs**	This factor captures the maintenance of traffic costs at the project site. MOT costs may impact preference due to its impact on total costs. Examples of this factor include costs associated with the maintenance of detours during construction and the preparation of detours prior to construction, signage, signals, barriers, temporary overlays, crossovers.
	Toll Revenue	This factor captures the loss of revenue due to the closure of a toll facility. Toll revenue may impact preference because it directly impacts total costs.
	Right of Way (ROW) Costs	This factor captures the cost to procure ROW. This factor may impact preference due to its impact on total costs. This factor includes either permanent or temporary procurements/easements.

Criteria	Sub criteria	Definition
Direct Costs	Costs to Develop Detour	This factor captures the costs to meet the requirements and to construct detour bridges to accommodate traffic through the project site. This factor may impact preference due to its impact on total costs. Examples of this factor include cost to design and to construct detour bridges and roads.
	Design/Project Development Costs	This factor captures the costs associated with the design of a bridge and costs related to project development based on the construction method. This factor may impact design preference and construction methods which directly affect total costs.
	Costs associated with Essential Services	This factor captures the costs associated with the need to provide essential services that may be impacted by the construction selected. Examples of this factor include alternate routes to provide defense, evacuation, emergency access to hospitals, schools, fire station, and law enforcement, etc.
	Construction Costs	This factor captures the estimated costs associated with the construction of the project. This factor may impact preference due to its impact on total costs. This factor includes premiums associated with new technologies or construction methods. Premiums might result from factors such as contractor availability, materials availability, and contractor risk.
	Agency Construction Management Costs	This factor captures the costs associated with the agency project oversight.
	Inspection, Maintenance and Preservations costs	This factor captures the costs associated with life cycle maintenance and preservation of individual bridge elements.
Indirect Costs	Loss of Revenue to Local Business	This factor captures lost revenues due to limited access to local business resulting from limited or more difficult access stemming from the construction activity.
	Impact to Neighborhood Livability during construction	This factor captures the impact to the neighborhoods resulting from construction activities. Examples of this factor include noise, delays, limited access. This factor may impact preference due to a desire to accelerate construction in order to minimize a neighborhood's exposure to construction activities.
	Costs of Users delay	This factor captures costs of delay at a project site due to reduced speeds and costs associated with delays, when using off-site detour routes. As an example, cost of queue times, which are calculated using ADT, delay time, and operating costs (driver and vehicle).
	Costs of Truckers delay	This factor captures trucker costs of delay at a project site due to reduced speeds and costs associated with delays, due to the use of off-site detour routes . As an example, cost of queue times, which are calculated by ADTT, delay time, and operating costs (driver and vehicle).
Schedule Constraints	Calendar or Utility or RR or Navigational Constraints	This factor captures the constraints placed on the project that might effect the timing of construction as a result of weather windows, significant or special events, railroad, or navigational channels. This factor may impact preference because certain construction methods may be more effective at accommodating these constraints.

Criteria	Sub criteria	Definition
	Marine and Wildlife Constraints	This factor captures the constraints placed on the project by resource agencies to protect marine or wildlife species. Examples of this factor include water work windows, migratory bird windows, nesting requirements, and etc.
	Resource Constraints	This factor captures resource constraints associated with the construction. A DOT may be resource-constrained in terms of staff available to design a project using a particular method or technology. This factor may impact preference since a state may be forced to go to a consultant, which may result in additional time requirements to get the consultant on board and deliver the project.
Work Zone Safety	**Safety Costs to traveling public**	This factor captures the risks associated with user exposure to the construction zone, including crash or accidents. Longer construction duration often results in higher user safety risk.
	Safety Costs to construction workers	This factor captures the risks associated with worker exposure to construction zone. Longer construction duration often results in higher worker safety risk.
Site Constraints	**Horizontal/ Vertical Obstructions**	This factor captures physical constraints that may impact construction alternatives. Examples include bridges next to fixed objects such as tunnels, ROW limitations, sharp curves or steep grades, or other urban area structures that constrain methods and/or bridge locations.
	Span Design	This factor captures criteria related to span design. The construction might require using simple spans or a continuous span. This element of the design may affect costs or owner preference.
	Archaeological Constraints	This factor captures archaeological and historical constraints existing on a construction site, which may impact a construction project. Decision makers would have a preference for construction methods that minimize the impact on the construction site environment.

5.0 FINAL DOCUMENTS AND SOFTWARE

During the last face-to-face meeting of the TAC team in Portland, OR in December 2010, the team discussed the list of criteria that was developed for this project and came up with a finalized criteria hierarchy. The highest level consists of five criteria, each of which is further specified by two to nine sub-criteria. The final criteria hierarchy is shown in Figure 5.1.

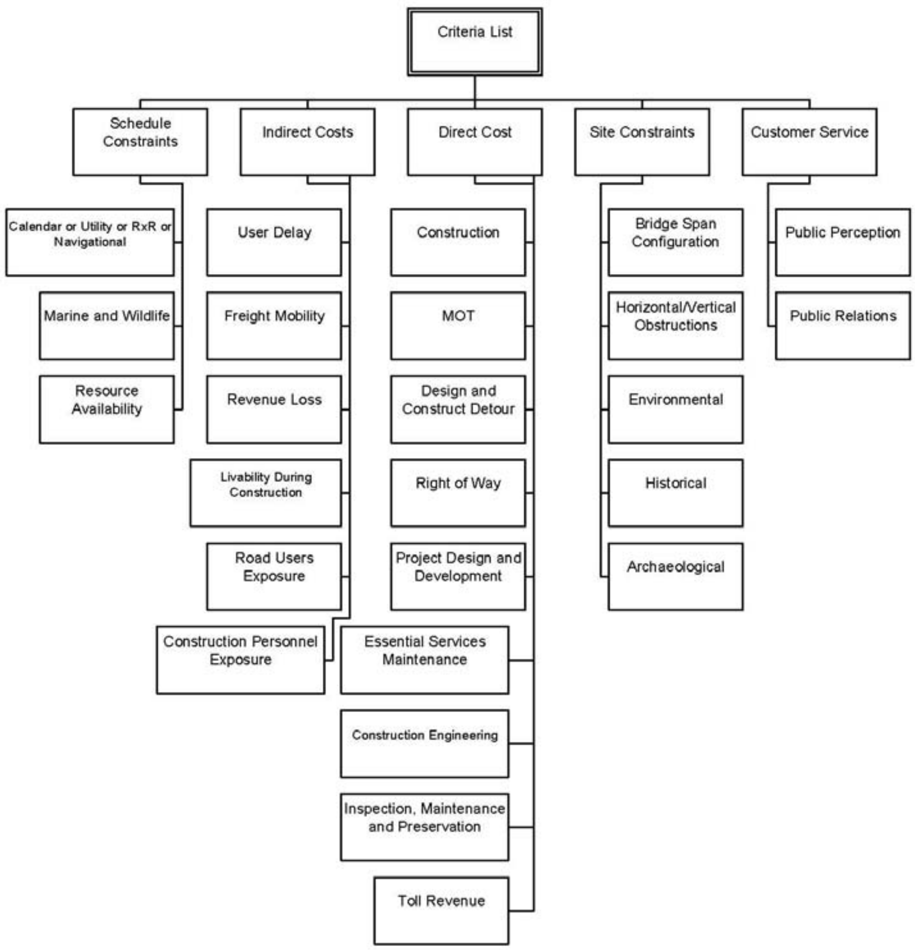


Figure 5.1: Final Decision Criteria Hierarchy

Based on the updated hierarchy, the team also updated the criteria definition list and the pairwise comparison survey list to reflect the changes in the hierarchy. The final versions of the criteria definition list and the paper-based AHP survey list are provided in Appendices F and G, respectively.

5.1. UPDATED SOFTWARE

Based on the feedback from the TAC team members, a few modifications were made to the ABC AHP Decision tool. The main updates in the latest version included:

1. A "Next Node" button was added to the "Pairwise Comparisons" tab, which allows the user to move to the next node in the hierarchy once the comparisons in the previous node are completed.
2. The buttons "Save Comparison" and "Save State" were removed from the "Pairwise Comparisons" tab.
3. The font size of the criteria and alternatives names in the "Pairwise Comparisons" tab was increased.
4. A "Summary Report" button was added to the "Results" tab, to allow the user to generate a Word file containing all the charts.
5. The alternatives' names that are defined by the user (using the "Set Alts." button in the first tab) can be saved for the project.
6. A label was added to the top of the comparisons page (survey list) in the last level of the hierarchy.

Other modifications made were mostly related to the software interface, the process for entering data, and the way in which the software displays results. Figure 5.2 illustrates the pairwise comparison tab in the final version of the software.

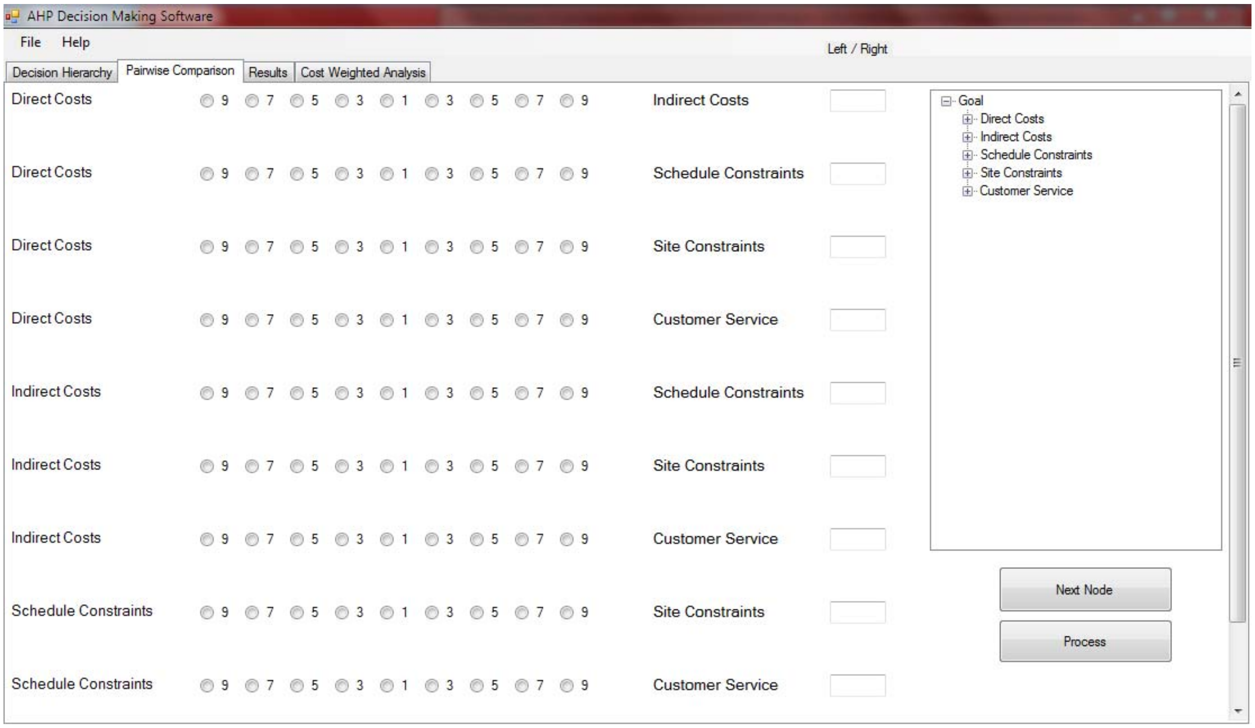


Figure 5.2: Updated Pairwise Comparison tab

The research team also created a comprehensive user manual for the developed software. The manual includes an introduction to the software and its Graphical User Interface (GUI), the various software features included in its four tabs, an overview of the AHP technique that the software uses, and the data structure used within the software. The user manual reflects the current version of the software.

5.2. AHP ANALYSIS REPORTS

The team collected more data on a number of completed or under construction bridges from the TAC member DOTs. A copy of the final AHP paper survey form was sent to each Department of Transportation in California, Iowa, Montana, Texas, Utah, Washington, and Oregon to be filled out by experts for at least one bridge replacement project in each state.

The data from the paper surveys were entered in the decision making software, and analysis reports were generated for each project using the AHP software analysis results. These reports were sent to the designated expert for review and approval. These reports are included in Appendix H.

6.0 DISSEMINATION EVENTS

To disseminate the results of the project, the team has made presentations at multiple conferences, seminars, webinars, and training sessions. The purpose of these presentations was to introduce transportation specialists, project managers, and engineers to the developed tool and its application to the decision-making process for choosing the best alternatives for bridge construction projects. The following section summarizes the presentations made to disseminate project findings.

6.1. EVERY DAY COUNTS REGIONAL INNOVATION SUMMIT IN VANCOUVER, WA

FHWA partnered with the American Association of State Highway and Transportation Officials (AASHTO) to sponsor ten Innovation Summits in fall 2010. The Northwest Summit was held in Vancouver, WA November 30 and December 1, 2010. EDC was designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment. These summits were critical to implementing FHWA-specific Every Day Counts strategies and technologies, which focus on shortening project delivery, accelerating technology deployment, and supporting innovation.

Dr. Doolen was the keynote presenter at lunch on November 30, 2010. The title of her presentation was “Multi-State ABC Decision Tool and Economic Modeling”.

6.2. TRB CONFERENCE IN WASHINGTON, D.C

The Transportation Research Board (TRB) 90th Annual Meeting was held in Washington, D.C., in January 2011 at the Marriott Wardman Park, Omni Shoreham, and Washington Hilton hotels. The information-packed program attracted 10,900 transportation professionals from around the world to Washington, D.C.

The TRB Annual Meeting program covered all transportation modes, with more than 4,000 presentations in nearly 650 sessions and workshops addressing topics of interest to all attendees—policy makers, administrators, practitioners, researchers, and representatives of government, industry, and academic institutions. More than 85 sessions and workshops addressed the spotlight theme for 2011: Transportation, Livability, and Economic Development in a Changing World.

Dr. Doolen presented “Economic Modeling Study” in the “Accelerated Bridge Construction: Research, Design, and Practice” session. She also presented the same topic during the Structures Committee session.

6.3. PBES ONLINE SEMINARS

To further support the FHWA's Every Day Counts initiative, a series of webinars covering technical details of PBES were scheduled on March 22, 23, 29, and 30, 2011 to support continued awareness and implementation of Prefabricated Bridge Elements and Systems (PBES) at the local transportation agency level. These sessions were hosted online and offered at no cost via the FHWA LTAP/TTAP Clearinghouse online Seminar Room.

Representatives from the concrete, lightweight concrete, steel, fiber reinforced polymer composites, and construction industries highlighted how their industry efforts and capabilities support the EDC-PBES deployment for accelerated bridge construction. The training included project –specific examples and case studies to highlight the benefits of PBES and accelerated bridge construction.

The target audience for this training was bridge and construction engineering staff from local transportation agencies and state DOTs as well as consultants and the contracting industry. The training included 12 individual topic modules scheduled for the convenience of audiences in the east, central/mountain, and west coast time zones.

Dr. Doolen and Ben Teng presented the topic of "ABC Decision Making and Economic Modeling Tool" in East coast, Pacific, and Central/Mountain sessions of this webinar on March 23 and 30, 2011. The session also covered the topics of "Lightweight Concrete Benefits for PBES Deployment" and "Construction Industry Efforts and Capabilities to Support PBES Deployment".

6.4. THE 6TH ANNUAL ACEC/ODOT PARTNERING CONFERENCE IN WILSONVILLE, OR

ODOT and the American Council of Engineering Companies - Oregon (ACEC) co-hosted the sixth annual partnering conference on April 27, 2011.This conference was for technical and project delivery staff from both private consulting firms and ODOT. The conference was located at the Holiday Inn - Wilsonville Conference Center in Oregon.

This conference provided information about ODOT's program direction and funding and tools that can be used to efficiently deliver projects. The keynote address was delivered by the nationally acclaimed professional futurist, Garry Golden. Garry's topic was "A 21st Century Roadmap: The Future of Infrastructure". The afternoon was devoted to break out sessions on a variety of topics.

At this conference, Dr. Doolen gave a presentation on the topic of "ABC Decision Tool and Economic Analysis" in the "ODOT Program Innovations to Support Practical Design" session.

6.5. NHI INNOVATIONS WEB CONFERENCE

Highways for LIFE partnered with the National Highway Institute (NHI) to produce NHI Innovations, a monthly Web-conference series that is free to participants. On May 19, 2011, Dr.

Doolen presented the topic of “To Accelerate Bridge Construction or Not” in a one and a half hour session at the NHI Innovations Web Conference.

6.6. THE 2011 ODOT BRIDGE DESIGN CONFERENCE IN SALEM, OR

ODOT scheduled the 2011 ODOT Bridge Design Conference for May 24th and 25th in Salem. The purpose of this conference was to provide a forum where information can be exchanged between ODOT, local and other governmental agencies, and consultants on topics of interest to the bridge design community.

The team presented the topic of “ABC Cost Analysis Decision Model” during the “Beyond Bridges” session on May 25, 2011.

6.7. THE 2011 INTERNATIONAL BRIDGE CONFERENCE IN PITTSBURGH, PA

The Traffic Management and Work Zone Safety workshop, sponsored by ARTBA’s National Work Zone Safety Information Clearinghouse, was held in conjunction with the International Bridge Conference on June 7 and 8, 2011 in Pittsburgh, PA. Dr. Doolen presented the decision making tool during this workshop with the topic of “New Decision Tool - Determining When to Use Accelerated Bridge Construction”.

6.8. THE 2011 MID-CONTINENT TRANSPORTATION RESEARCH SYMPOSIUM IN AMES, IA

On August 18-19, 2011, the 2011 Mid-Continent Transportation Research Symposium was hosted by the Institute for Transportation (InTrans) at Iowa State University and was organized by InTrans and the Iowa Department of Transportation. The location of the symposium was Gateway Hotel and Conference Center at Ames, Iowa.

The symposium’s technical program included keynote and plenary sessions, a poster session, and several breakout sessions. There were six concurrent breakout sessions during five time slots on both days of the symposium. The breakout sessions included podium-based and interactive presentations.

In the evening of August 18th, the team attended session two of the “Structures and Bridges” track and presented the topic of “ABC Decision Tool and Economic Modeling Study”.

6.9. WESTERN BRIDGE ENGINEERS’ SEMINAR IN PHOENIX, AZ

The Western Bridge Engineers' Seminar is a biennial cooperative effort by the Federal Highway Administration and the Transportation Departments of Alaska, Arizona, California, Idaho, Nevada, Oregon, and Washington. Its purpose is the exchange of information between government agencies, consultants, contractors, educators, and suppliers on current subjects important to the design, construction, and maintenance of bridges.

The 2011 Western Bridge Engineers' Seminar was hosted by the Arizona Department of Transportation. The Seminar was held on September 25-28, 2011 at the Arizona Grand Hotel in Phoenix. On September 27, 2011, Dr. Doolen presented the topic of "A Planning Phase Decision Tool for ABC" during the “Guidelines and Specifications” session at this seminar.

6.10. TWENTY-SIXTH ANNUAL CIVIL ENGINEERING PROFESSIONAL DEVELOPMENT IN WEST LAFAYETTE, IN

On November 17, 2011, the 26th annual Civil Engineering Professional Development Seminar was held at Purdue University in West Lafayette, IN. The seminar was cosponsored by Metropolitan Indianapolis Branch of American Society of Civil Engineers and School of Civil Engineering, Purdue University. The seminar included sessions on Management, Transportation, Sustainability, Environmental/Hydraulics, and Bridge/Structural.

The team attended the “Bridges/Structural” session and presented the topic of “A Planning Phase Decision Tool for Accelerated Bridge Construction”.

6.11. NORTHWEST TRANSPORTATION CONFERENCE IN CORVALLIS, OR

The Northwest Transportation Conference, formerly known as the Northwest Roads and Streets Conference, has been held approximately every two years since 1949. The conference has served as a forum for engineers, designers, builders, operators and other transportation officials from Oregon and Washington with attendance ranging from 300 to 500 participants. Conference topics have included all aspects and modes of transportation, from maintenance techniques and design standards to funding and organizational issues.

The theme for the upcoming conference is ***“Transportation and the Economy***”. It will be held at Oregon State University in Corvallis, OR on February 7-9, 2012.

On February 8, 2012, the team is going to present the topic of “A Decision Tool for Accelerated Bridge Construction” during the “Structures” session.

6.12. TRAINING SESSIONS

The team conducted three training sessions in Oregon to introduce ODOT managers and engineers to the “Accelerated Bridge Construction Decision Making Process Using AHP Software.” Laptops were provided in these three hour sessions for participants to work with the developed software and learn about the process of building the hierarchy, entering data in the software, and interpreting the results.

The first two training sessions were held in an ODOT building in Portland on May 12, 2011 and April 6, 2011 and the third one was held in Salem on August 16, 2011.

6.13. PUBLICATION

An article titled “To Accelerate Bridge Construction or Not? A Planning Phase Decision Tool for ABC” was submitted by the team to the “Public Roads Magazine” (a FHWA publication) and was accepted for publication in the Nov/Dec 2011 issue of the magazine. In this paper, the developed tool for ABC decision making process is introduced.

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APPENDIX A
LITERATURE REVIEW DOCUMENTS AND CITATIONS

	Title	Author(s)	Year	Topic
1	Processes and Techniques for Rapid Bridge Replacement After Extreme Events	Y. Bai and S. H. Kim	2007	PBES Techniques and Innovation
2	Review of Work Zone Impact Mitigation Techniques: Achieving the Objective of Reducing Vehicle Emission	S. Wongwitdecha, Ph.D., Kasetsart University Visiting Researcher, JSPS Core University Program 2004	2004	Work zone safety
3	Highways for LIFE Economic Analysis	Highway for Life	N/A	Cost Estimation
4	Assessing Cost of Travel - Annual Update	Urban Planning Office and Freight Systems Division, WSDOT	2009	Cost Estimation
5	Accelerated Construction Decision Making Process	T. P. Arurkar	2005	Decision Making
6	Accelerated Construction Decision-Making Process For Bridges	S. Salem, PhD., P.E, CPC and R. Miller, PhD., P.E	2006	Decision Making
7	Innovative Technology for Accelerated Construction of Bridge and Embankment Foundations in Europe	FHW A-PL-03-014	2003	PBES Techniques and Innovation
8	Accelerated Bridge Construction	M. L. Ralls	2007	PBES Techniques and Innovation
9	Rapid Bridge Replacement: Processes, Techniques, and Needs for Improvements	Y. Bai, Ph.D., M.ASCE and W. R. Burkett, A.M.ASCE	2006	PBES Techniques and Innovation
10	Benefits and Costs of Prefabricated Bridges White Paper	Utah Department of Transportation	2008	Cost Estimation
11	Caltrans ABC Strategic Plan: Development of practice and policy for Future bridge projects	ABC- Advisory Council	2008	Decision Making

	Title	Author(s)	Year	Topic
12	Get In, Stay In, Get Out, Stay Out.	M. Vasant and M. Al	2006	PBES Techniques and Innovation
13	Standard question arise in DOT's acceptance of SSC	T. Kuennen	2006	PBES Techniques and Innovation
14	Economic Evaluation Methods For Assessing Value Of Accelerated And Durable Construction Options In Early Design Stages	K. F. Reinschmidt and D. Trejo, Texas A&M	2005	Cost Estimation
15	WSDOT Strategic Plan Accelerated Bridge Construction (ABC)	WSDOT	2009	Decision Making
16	Applying LCCA to Bridges	Al-Wazeer, Adel, Harris, Bobby, Nutakor, Christopher, Public Roads	2005	Cost Estimation
17	Comparison of construction costs on motor way projects using measure and value and alternative tendering initiative contractual arrangements	D. A. Langford, P. Kennedy, J. Conlin and N. Mckenzie	2003	Cost Estimation
18	Estimating User Costs and Economic Impacts of Roadway Construction in Six Federal Lands Projects	M. H. Hardy, J. J. Larkin, K. E. Wunderlich, and A. J. Nedzesky	2007	Cost Estimation
19	Framework for Prefabricated Bridge Elements and Systems (PBES) Decision-Making	FHWA	2005	Decision Making
20	Crash Analysis And Reporting Unit Continuos System Crash Listing	ODOT	2004	Safety
21	Crash Analysis And Reporting Unit Continuos System Crash Listing	ODOT	2008	Safety
22	Final Report Highways for Life Report	ODOT	2009	PBES Techniques and Innovation

	Title	Author(s)	Year	Topic
23	Evaluation of Life-Cycle Cost Analysis Practices Used by the Michigan Department of Transportation	A. Chan, G. Keoleian, and E. Gabler	2009	Cost Estimation
24	Multi objective Linear Programming Model for Scheduling Linear Repetitive Projects	P. G. Ipsilandis	2007	Decision Making
25	M115 economic analysis	MDOT	2009	Cost Estimation
26	Model for Analysis of Factors Affecting Construction Schedule in Highway Work Zones	P. Sukumaran, M. EmreBayraktar, T. Hong, and M. Hastak	2006	Decision Making
27	Innovative Features of this Project (Return on Investment)	ODOT	2009	Cost Estimation
28	Prefabricated Bridge Elements and Systems in Japan and Europe	M. L. Ralls, B. Tang, Sh. Bhidé, B. Brecto, E. Calvert, H. Capers, D. Dorgan, E. Matsumoto, C. Napier, W. Nickas, H. Russell	2005	PBES Techniques and Innovation
29	PBES Cost Study: Accelerated Bridge Construction Success Stories	FHWA	2006	PBES Techniques and Innovation
30	Evaluating Public Transit Benefits and Costs - Best Practices Guidebook	T. Litman, Victoria Transport Policy Institute	2010	Cost Estimation
31	Maine Demonstration Project: Reconstruction of Lamson and Boom Birch Bridges	Ch. Churilla, J. Mallela, G. Hoffman	2008	PBES Techniques and Innovation
32	Benefits & Costs of Prefabricated Bridges	M. L. Ralls, P.E., UDOT	2008	Cost Estimation

	Title	Author(s)	Year	Topic
33	THE 2007 URBAN MOBILITY REPORT	D. Schrank and T. Lomax, Texas A&M	2007	Various
34	Manual on Use of Self-Propelled Modular Transporters to Move Bridges	FHWA, AASHTO, NCHRP, FDOT	2007	PBES Techniques and Innovation
35	Innovative Prefabrication in Texas Bridges	R. Medlock, M. Hyzak, and L. Wolf	N/A	PBES Techniques and Innovation
36	Proposed Doctrine for Accelerated Bridge	J. P. Hanus, PhD, PE Lieutenant Colonel, US Army United States Military Academy	N/A	PBES Techniques and Innovation
37	National Perspective on Accelerated Bridge Construction	V. Mistry, FHWA	2007	PBES Techniques and Innovation
38	Construction and Testing of an Accelerated Bridge Construction Project in Boone County	IOWA DOT	2007	PBES Techniques and Innovation
39	SPMTs: Your Guide to Accelerated Bridge Construction	FHWA-HRT-08-009	2007	PBES Techniques and Innovation
40	Marketing Plan for Prefabricated Bridge Elements and Systems (PBES)	FHWA	2007	Cost Analysis
41	Accelerated Bridge Construction Applications in California - A lessons learned report	Caltrans	2008	Decision Making
42	Innovative Bridge Design for Rapid Renewal	K. Price, HNTB	2009	PBES Techniques and Innovation
43	Texas DOT Accelerated Construction Strategies Guideline	TXDOT	2003	Strategic Planning

	Title	Author(s)	Year	Topic
44	2010 FHWA Bridge Engineering Conference: Highways for Life and Accelerated Bridge Construction	FHWA	2010	PBES Techniques and Innovation
45	LRFD Concrete Bridge Design	B. Khaleghi	2010	PBES Techniques and Innovation
46	Steel Bridge Design using AASHTO LRFD Bridge Design Specification (2009 Edition)	A. Azizinamini	2010	PBES Techniques and Innovation

APPENDIX B
DOCUMENT SUMMARIES

The number in front of each title is the number of the document in Appendix A.

Rapid Techniques (1)
This paper talks about processes and techniques for rapid bridge replacement after extreme events. To achieve the research objectives, the team studied three cases of previous bridge replacements following extreme events. These cases are the I-40 Webbers Falls Bridge in Oklahoma, the I-95 Chester Creek Bridge in Pennsylvania, and the I-87 New York State Thruway Bridge in Yonkers, New York.

Work zone impact mitigation techniques (2)
This research focuses mainly on the two primary concerns of work zone impacts: delay and excess air pollution. The research objective is to explore techniques that are used by different road agencies in order to minimize traffic delay, and so as to minimize air pollution impacts during road construction. These include techniques that enhance the flow of traffic in work zones and/or accelerate the construction duration.

ABC Full Coverage Europe (7)
FHWA scan team met in Europe with technical and industry leaders to identify and evaluate innovative European technologies in accelerated bridge construction.
Status of limit state design (Technical Barriers). The overall goal of the scan trip is to implement technologies of best practice in the United States. With this objective clearly in mind, team members developed an implementation ranking.

Accelerate_bridge_spr07 (8)
Accelerated construction techniques with examples of successful projects.

Bai_2006 (9)
Rapid bridge replacement processes and techniques. Starting from contracting procedures, detouring, demolishing, etc. This paper contains separate sections for community and interagency cooperation and comments about necessary improvements or recommendations.

Benefits_and_Costs_of_Prefabricated_Bridges_05_30_08 (10)
Contains information about several projects conducted with prefabricated elements. Discusses both construction and user costs (with real numbers from previous projects). Includes Costs of Prefabricated Bridges (construction and delay-related user costs).

Caltrans_ABC_Strategic_Plan_V1-1 (11)
ABC decision criteria and type selection, lessons learned from past. Industry engagement and technical research. This paper summarized tasks needed to develop a conversation formula to calculate cost of traffic delays.

Get in Get out Stay out (12)
The article discusses the effective use of accelerated bridge construction (ABC) solution by several state departments of transportation, related agencies and contractors in the U.S. One particular ABC method involves maximizing prefabrication.

Precast (13)
Mainly talks about precast advantages and procedures.

Trejo_Economical_Evaluation (14)
Economic evaluation methods for assessing value of accelerated construction options and life cycle costs. This paper presents simple, quick methods for evaluating the economical advantages of accelerating construction projects (reducing project durations).

WSDOT_ABC_Strategic_Plan (15)
Washington DOT strategic plan for ABC. Contains ABC selection criteria, decision check list and matrix , cost benefit development, and technical aspects of ABC.

Applying LCCA to Bridges (16)
This paper is about an economic tool called LCCA. This economic analysis tool can help determine the best option for infrastructure projects by calculating the lowest cost over their life cycles. The paper also introduces other existing tools for bridges that use LCCA analysis.

Comparison of construction costs (17)
This paper reports the outcome of an investigation into the construction costs in 11 motor way projects.

Estimating user delay costs (18)
Estimating User Costs and Economic Impacts of Roadway Construction in Six Federal Lands Projects. As part of this study, FLH–QuickZone is developed to help estimate these soft costs of roadway construction.

Framework PBES Decision Making (19)
This report presents a framework for the objective consideration of the above-mentioned issues. As such, the framework is a decision-making tool to help answer the ultimate question of whether a prefabricated bridge is achievable and effective for a specific bridge location.

Highways for Life Final (22)
This report is to document the program requirements as defined in the Highways for Life Grant Application, January 24, 2007. It has estimations for user saving costs due to traffic improvements.

LCCA in Michigan (23)
The primary purpose of this study is to evaluate the accuracies of the LCCA procedure used by MDOT in the pavement design stage in projecting the life-cycle costs and maintenance schedules of different pavement types, and thereby choosing the lowest-cost pavement type. Based on the four case studies, all the LCCA procedures in the case studies were able to predict the pavement type with lower initial construction cost, although the amount of the initial costs was subject to estimation error. It has a section devoted to FHWA guidance toward using LCCA.

M115 economic analysis section (25)
For this economic analysis, MDOT supplied most of the cost figures for the as-built project. The assumptions for the baseline case costs were determined from discussions with MDOT.

Model example (26)
Model for analysis of factors affecting construction schedule in highway work zones. This paper presents a model that identifies various factors which have a potential to influence and impact the construction schedule in highway work zones. Also, a stochastic analysis of those factors is conducted by the model to determine probable changes, i.e., reduction or escalation, in the original estimated schedule for a given project.

OR Economic analysis (27)
In this paper a discussion of the time savings associated with some of the mobility measures employed by the Contractor on Bundle 401 is presented. StratBENCOST was used to estimate the monetary value of those time savings.

PBES in Europe and Japan (28)
In April 2004, a team of bridge engineers, sponsored by the Federal Highway Administration (FHWA), AASHTO, and NCHRP visited Japan and Europe to investigate innovations in prefabricated bridge building technology. A number of useful technologies were identified on that trip such as prefabricated bridge elements and systems that minimize traffic disruption, improve work zone safety, and lower life-cycle costs.

PBESfinal_report 2006 (29)
Accelerated Bridge Construction Success Stories.

Public Transit Benefits and Costs (30)
This guidebook describes how to create a comprehensive framework for evaluating the full impacts (benefits and costs) of a particular transit service or improvement. It identifies various categories of impacts and how to measure them. It discusses best practices for transit evaluation and identifies common errors that distort results. It discusses the travel impacts of various types of transit system changes and incentives. It describes ways to optimize transit benefits by increasing system efficiency, increasing ridership and creating more transit oriented land use patterns. It compares automobile and transit costs, and the advantages and disadvantages of bus and rail transit. It includes examples of transit evaluation, and provides extensive references. Many of the techniques in this guide can be used to evaluate other modes, such as ride sharing, cycling and walking.

Report_012309 Maine (31)
The Maine DOT submitted application and was approved for FY 2007 Highways for LIFE program funding. The Maine projects are two bridges.

UDOT White Paper on Benefits & Costs of Prefab Bridges_updated (32)
A complete summary on construction costs and user related costs for prefabricate bridge construction.

2007 Urban Mobility Report (33)
This paper contains urban mobility report for year 2007. The paper describes problems caused by congestion and discusses a number of solutions. The paper contains a comprehensive database for national congestion information.

FHWA Manual Self-propelled (34)
This manual contains information on the equipment, benefits, costs, project selection criteria, planning, design, contracting issues, and example contract documents for using self-propelled modular transporters to move bridges. Self-propelled modular transporters are multi-axle devices that can be manipulated in very limited spaces to move complete prefabricated bridge systems into position. It also includes case studies and lessons learned from previous projects. The manual is intended for use by bridge owners, construction contractors, suppliers, and other professionals involved in bridge design and construction.

Technical_innovative_prefab (35)
The paper is about innovative prefabricated systems and elements in Texas bridges.

PBES Marketing Plan May 2007 (40)
FHWA Marketing Plan published in 2007. The paper also have some good discussions on costs and barriers to ABC.

ABC_LessonsLearned_v1-1 (41)
This is a “Lessons Learned” report from Caltrans. It contains California’s successful ABC projects completed in the last 5 years.

SHRP2-R04 Chapter 4 Resubmission Clean (42)
This reports contains results for surveys, interviews, and group discussions created to gain insight into the successful practices of bridge owners engaged in ABC and to learn about the challenges faced by bridge owners who have not been successful with ABC. The survey contains 40 questions which focus on ABC goals, practices, experiences, hindrances, and opinions. The advanced tools of the survey allow for questions to be shown or hidden according to the responder’s answers so only the questions determined to be applicable were answered.

Strategy Guidelines Texas (43)
This document contains Texas DOT strategic plans for using Accelerated Bridge Construction techniques. Goals for accelerating traffic disrupt projects are established. Background on ABC in Texas is provided. Content on road user costs, contracting guidelines, CPM schedule development is provided.

2010 FHWA Bridge Conference Proceedings.pdf (44)
This document contains abstracts and papers from 2010 FHWA Bridge Engineering Conference: Highways for Life and Accelerated Bridge Construction. The papers introduce and provide technical information about innovative bridge construction techniques**Concrete Workshop (45)**
Presentation notes on LRFD concrete bridge design during 2010 FHWA Bridge Engineering Conference

Steel Workshop (46)
Presentation notes on Steel bridge design during 2010 FHWA Bridge Engineering Conference

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APPENDIX C
SUMMARY OF CONSTRUCTION PROJECT DECISION MAKING PROCESSES USED IN CALIFORNIA, FHWA, OREGON, TEXAS, UTAH, WASHINGTON

California Transportation Decision Making Model

Project Delivery: Design Impact Questionnaire

Given: Construction Impact Time (CIT), and Construction Completion Time (CCT)

Structure Type: *CIP, Precast, or other types of construction*

Questions	No / Yes (1 2 3 4 5)	Priority Low 1 / High 2	Score
General — # of Items 6			
1. Is this an emergency bridge replacement?			0
2. Is bridge on an emergency evacuation route or over railroad/waterway?			0
3. Is there a funding requirement to accelerated project delivery?			0
4. Is rapid recovery or completion of planned repair/replacement needed?			0
5. Is the bridge construction a critical path of the total project?			0
6. Are there significant economic benefits if construction is completed ahead of schedule?			0
	Individual Category Score =		0
Traffic — # of Items 5			
7. Bridge carries high ADT or ADTT?			0
8. Bridge over existing high ADT or ADTT facility?			0
9. Bridge construction significantly impact traffic? (Does it have high user-delay costs?)			0
10. Can the bridge be closed during off-peak traffic periods?			0
11. Will the traffic control plan be significantly impacted?			0
	Individual Category Score =		0
Construction — # of Items 3			
12. Do worker safety concerns at the site limit conventional methods? (e.g. adjacent power lines or over water?)			0
13. Is the bridge location subject to construction time restrictions due to adverse economic impact?			0
14. Does the site create problems for conventional construction methods? (e.g. falsework, concrete delivery, etc.?)			0
	Individual Category Score =		0
Utilities — # of Items 2			
15. Are there existing utilities/Railroad that impact the construction window?			0
16. Are there existing utilities/Railroad that impact construction operations?			0
	Individual Category Score =		0
Environmental — # of Items 4			
17. Is the site environmentally sensitive area requiring minimum disruption? (e.g. wetlands, air quality, and noise?)			0
18. Are there natural or endangered species at the bridge site? (Shorten construction window needed?)			0
19. Local weather limit the time of year for construction?			0
20. Is the bridge on or eligible for the National Register or Historic Places, or a designed landmark structure?			0
	Individual Category Score =		0
		Total Score =	**0**

ABC structure alternative is recommended for the APS if either:

i) Total score > 120

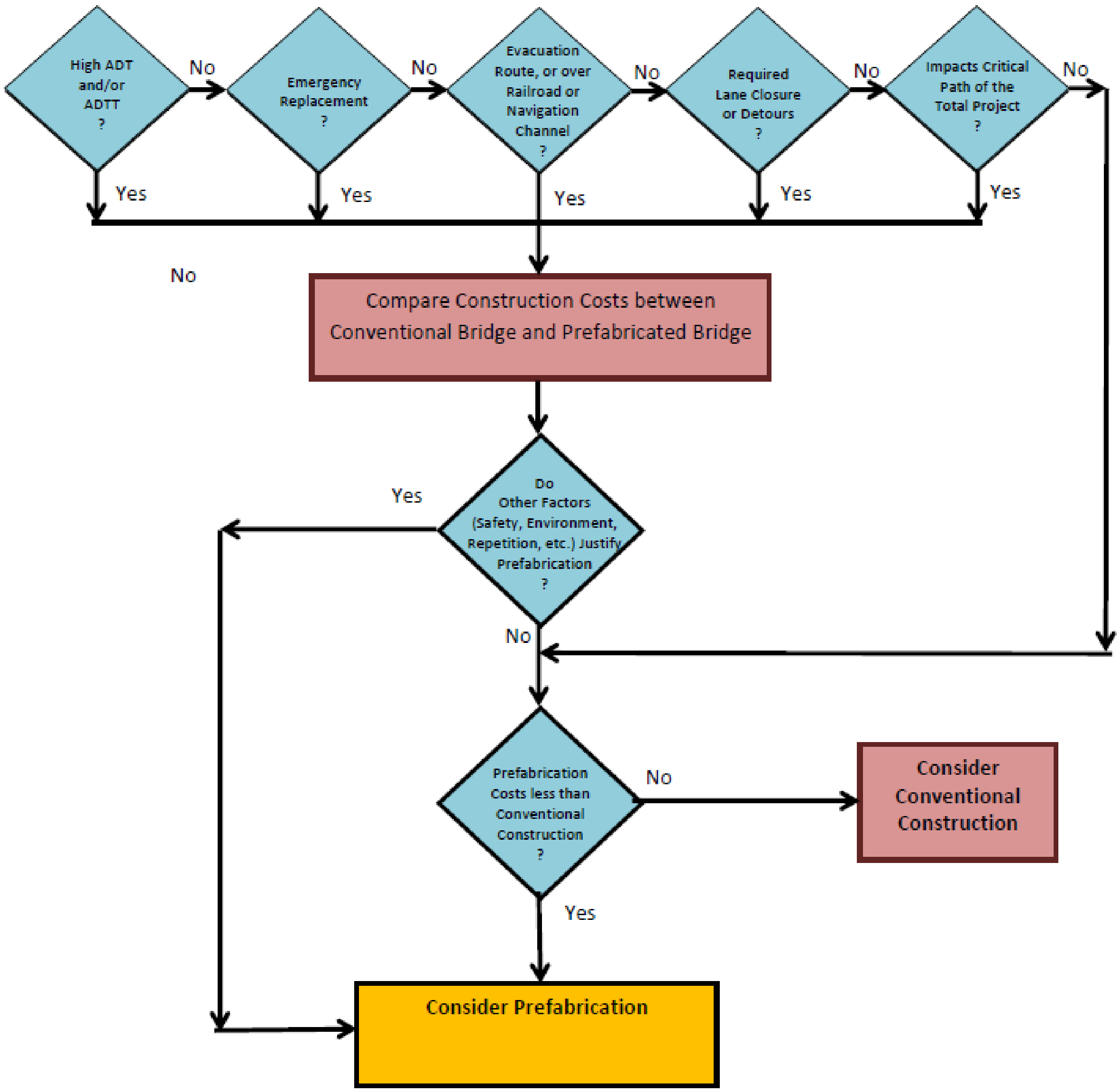
ii) Individual category score makes it eligible for ABC alternative

(PDT to decide which individual category(ies), if any, can activate the ABC recommendation)

Notes: 1) A high priority score of 2 is used for items of most importance.

2) 1.5 should be used for moderate priority

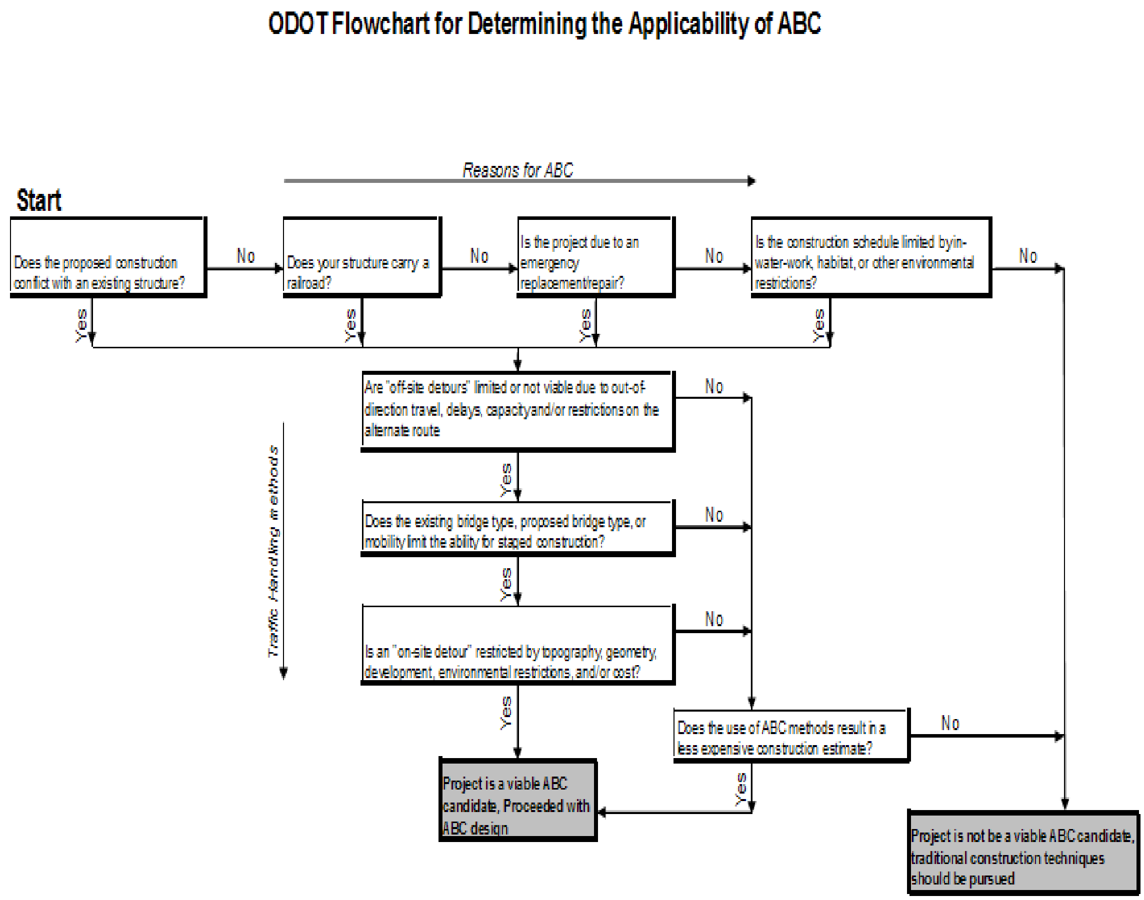
FHWA Decision Making Model



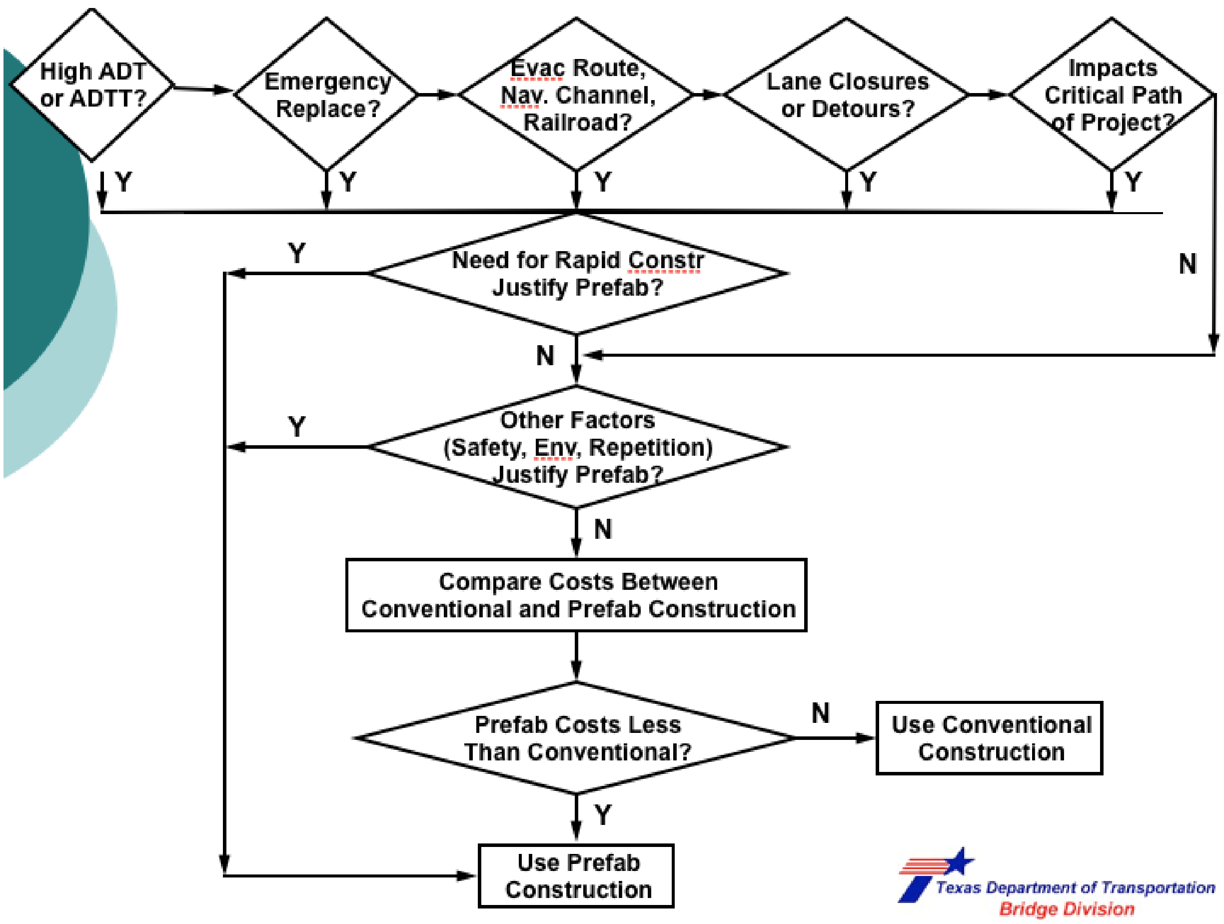
FHWA Decision Making Model (continued)

Question	Yes	Maybe	No
Does the bridge have high average daily traffic (ADT) or average daily truck traffic (ADTT), or is it over an existing high-traffic-volume highway?			
Is the bridge over a railroad or navigable waterway, or is it on an emergency evacuation route?			
Will traffic be subject to back-ups when using the bridge during construction, or be subject to excessive detours during construction of the bridge?			
Is this project an emergency bridge replacement?			
Must traffic flow be maintained on the bridge during construction?			
Can the bridge be closed during off-peak traffic periods, e.g., nights and weekends?			
Does the bridge have multiple identical spans?			
Can the bridge be grouped with other bridges for economy of scale?			
Will roadway construction activities away from the bridge be completed quickly enough to make rapid installation of a prefabricated bridge a cost-effective solution?			
Can adequate time be allocated from project award to site installation to allow for prefabrication of components to occur concurrently with site preparation?			
Do worker safety concerns at the site limit conventional methods, e.g., adjacent power lines or over water?			
Is the site in an environmentally sensitive area requiring minimum disruption (e.g., wetlands, air quality, noise, etc.)?			
Is the bridge location subject to construction time restrictions due to adverse economic impact?			
Are there natural or endangered species at the bridge site that necessitate short construction time windows or suspension of work for a significant time period, e.g., fish passage or peregrine falcon nesting?			
If the bridge is on or eligible for the National Register of Historic Places, is prefabrication feasible for replacement/rehabilitation per the Memorandum of Agreement?			
Is the bridge site accessible for delivery of prefabricated components or use of heavy lifting equipment?			
Does the location of the bridge site create problems for delivery of ready-mix concrete?			
Does the local weather limit the time of year when cast-in-place construction is practical?			
Does the height of substructures make use of formwork to construct them inconvenient or impractical?			
Are fabricators available to economically manufacture and deliver the required prefabricated components?			
Are there contractors available in the area with sufficient skill and experience to perform prefabricated bridge construction?			
Does the height of the bridge above ground make false work uneconomical or impractical?			
Totals:			

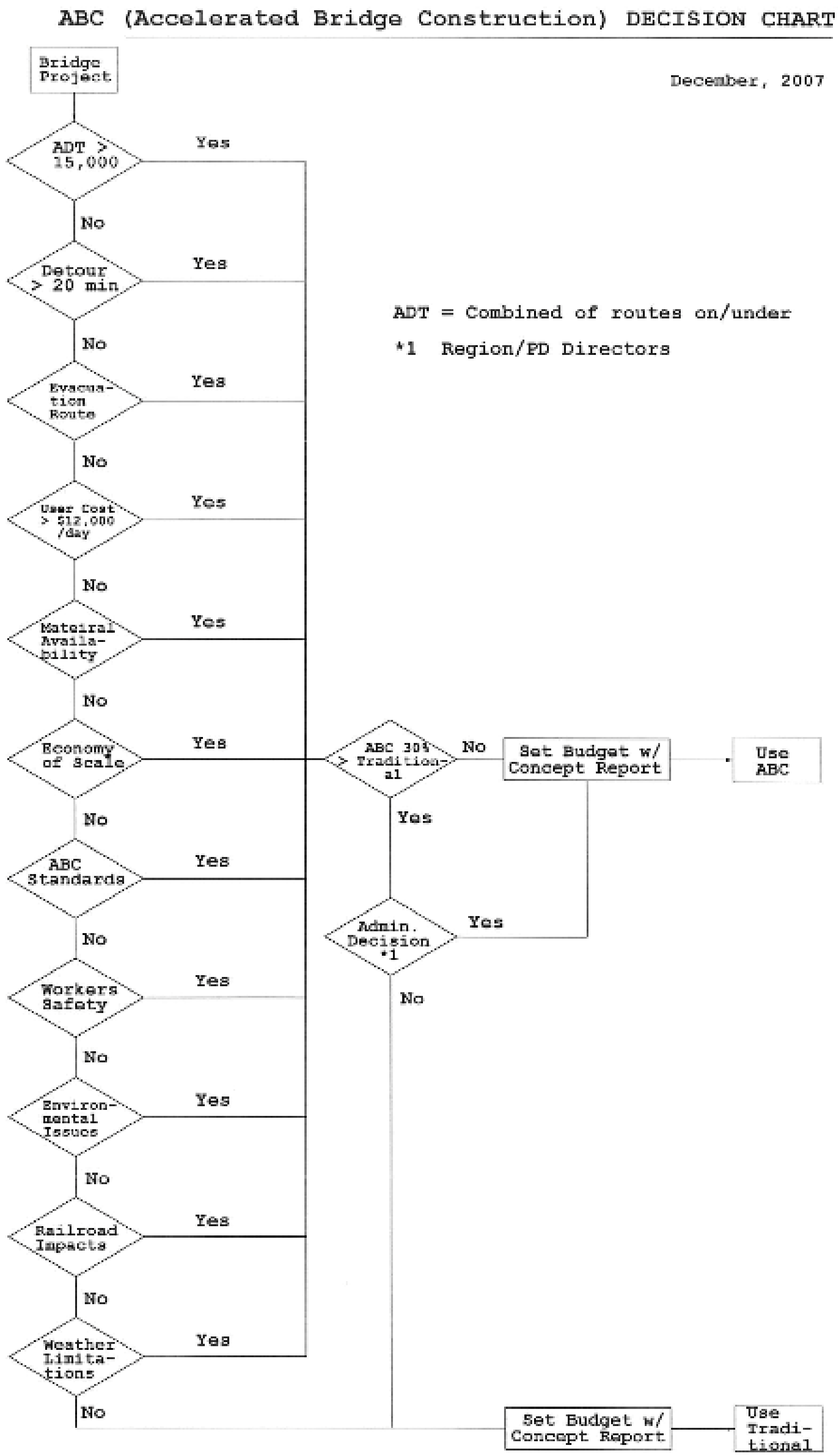
Oregon DOT Decision Making Model



Texas DOT Decision Making Model



Utah DOT Decision Making Model



Washington DOT Decision Making Model

ABC Decision Making Checklist

	Question	Yes	Maybe	No
1	High traffic volume			
2	Emergency replacement			
3	Worker safety concerns			
4	High daily traffic control costs			
5	Evacuation route or over railroad or navigable channel			
6	Lane closures or			
7	detours			
8	Critical path of project			
9	Close during off-peak traffic			
10	Rapid recovery/repair required			
11	Adverse economic impact			
12	Weather constraints			
13	Environmentally sensitive site			
14	Natural or endangered species			
15	Feasibility if historic bridge			
16	Multiple similar spans (segments)			
17	Problem for ready-mix concrete			
18	Delay-related user cost concern			
19	Innovative contracting strategies			
20	Group with other bridges			
21	Future use			
	Totals			

APPENDIX D
PRELIMINARY DECISION CRITERIA LIST AND DEFINITIONS

Category	Variable	Units	Notes	Reported by:	Type
Direct Cost	Toll Revenue	dollar	This is the loss or revenue due to a closure of a toll facility should the ABC project elect to close the faculty		Quantitative
Direct Cost	Delta Right of Way Costs	dollar	This is the difference in cost to procure ROW between ABC and Conventional Construction. Either permanent or temporary procurements/easements.	ROW Staff	Quantitative
Direct Cost	Delta Maintenance of Traffic (MOT) Costs	dollar	This is the difference in the maintenance of traffic costs ABC and Conventional Construction at the project site. Includes costs associated with the maintenance of detours during construction and the preparation of detours prior to construction. Examples include: signage, signals, barriers, temporary overlays, crossovers, , Capturing this cost may require a traffic control plan be developed for each alternative including temporary structures. Or possibly use estimates used based on DOT experience. This may need to broken down into multiple variables so that persons reporting data can provide proper input.	roadway/ traffic staff	Quantitative
Direct Cost	Delta Costs to Construct Detour Bridges	dollar	This is the difference in the requirements to construct detour bridges to accommodate traffic through the project site ABC and Conventional Construction at the project site. Cost to construct detour bridges	Bridge Staff	Quantitative
?	Number of Spans	?	The ABC construction might require using simple spans versus using continuous spans under a convention issue. This is a design decision that may have effect on cost or an owner's preference over the type of bridges put into their inventory, i.e. bridges with joints.	?	Quantitative
Site Constraints	Horizontal/Vertical Obstructions	Yes/No	Physical constraints dictate construction alternatives. Such as bridges next to tunnels, ROW limitations, bridges on sharp curve or steep grade, urban areas with bridges on both sides which lock the bridge into a single site.	Bridge or Roadway Designers	Qualitative

Direct Cost	Delta Design/Project Development Costs	dollar	These are the difference in costs associated with the design of a bridge. This may be influenced by the designer experience with ABC and/or specific ABC elements and could be a +/- costs. For example; a state that has institutionalized ABC it may cost more in design to go back to conventional design. Additionally, there may be delta costs related to project development based on the construction method, for example if the construction method avoids impacts to the environment then the cost to obtain permits could be reduced. There is also the ability to mitigate impacts by using a certain construction method (this may not be measurable).	Bridge or Roadway Designers	Quantitative
?	Resource Constraints	Yes/No	A DOT may be resource constrained in terms of staff available to come up to speed on ABC. Whereas the conventional designs may be expedited through the use of standard designs or similar designs. A state may be forced to go to a consultant that may require additional time to get the consultant on board and deliver the project.	Bridge or Roadway Designers	Qualitative
Indirect Costs	Delta Loss of Revenue to Local Business	time or dollars	This is the difference in lost local business revenues due to limited access to local business due to construction activity or people don't want to go through construction zone to visit local businesses.		Quantitative
Direct Cost	Delta costs associated with Essential Services	dollar	This is the difference in costs associated with the need to provide essential services that may be impacted by the type of construction selected. For example; If the bridge is shut down, is there an acceptable alternate route to provide defense, evacuation, emergency access to hospitals, schools, fire station, and law enforcement, etc.		Quantitative
Indirect Costs	Impact to Neighborhood Livability during construction	time	This is the impact to the neighborhoods due to construction activities i.e. noise, delays, limited access. There may be a desire to accelerate construction in order to minimize a neighborhoods exposure to construction activities.		Quantitative
Customer Service	Impact to Neighborhood Livability during construction	time	This is the impact to the neighborhoods due to construction activities i.e. noise, delays, limited access. There may be a desire to accelerate construction in order to minimize a neighborhoods exposure to construction activities.		Quantitative

Indirect Costs	Delta Costs of Users delay	dollar	Includes POV costs of delay at project site due to reduced speeds and costs associated with delays due to the use of off-site detour routes . Includes cost of queues times. Calculate by ADT, delay time, operating costs (driver and vehicle).		Quantitative
Indirect Costs	Delta Costs of Truckers delay	dollar	Includes Truckers costs of delay at project site due to reduced speeds and costs associated with delays due to the use of off-site detour routes . Includes cost of queues times. Calculate by ADTT, delay time, operating costs (driver and vehicle).		Quantitative
Work windows	Calendar or Utility or RR or Navigational Constraints	time	These are the constraints placed on the project that might effect the timing of the project including weather windows, significant or special events, RR needs, navigational channels. One type of construction may have advantages over other with regards to accommodating these "events".		Quantitative
Work windows	Marine and Wildlife Constraints	time	These are the constraints placed on the project by resource agencies to protect marine or wildlife species. Including in water work windows, migratory bird windows, nesting requirements, etc.		Quantitative
Safety	Delta Safety Costs to traveling public	dollar	These are the delta costs associated with the user exposure to construction zone, including crashes accidents. The generally idea is that the longer construction duration results in higher risk to safety. This could be based on accident rates which may be based on ADT levels.		Quantitative
Safety	Delta Safety Costs to construction workers	dollar	These are the delta costs associated with the workers exposure to construction zone. The general idea is that the longer construction duration results in higher risk to safety.		Quantitative
Direct Cost	Delta Construction Costs	dollar	These are the delta estimated costs associated with the construction of the project. This item should include premiums associated with new technologies or construction methods. The premium is intended to address contractor availability, materials availability, and contractor risk.		Quantitative
Direct Cost	Delta Agency Construction Management Costs	time	This is the delta costs associated with the agency project oversight costs.		Quantitative
Direct Cost	Delta in maintenance and preservations costs	dollar	This is the costs associated with the life cycle maintenance and preservations costs associated with the individual bridge elements or overall bridge design.		Quantitative

APPENDIX E
PRELIMINARY AHP SURVEY

Cover Sheet for Preliminary Version of AHP Survey

"What is the worth of a specific bridge construction technique in terms of a customer service criterion?"

Although information about questions like the previous one are vital in making the correct decision, it is very difficult, if not impossible, to quantify them correctly. Therefore, many decision-making methods attempt to determine the relative importance, or weight, of the alternatives for each criterion involved in a given decision-making problem.

Pairwise comparisons are used to determine the relative importance of each alternative for each criterion. In this approach the decision-maker has to express his opinion about the value of one single pairwise comparison at a time.

Each choice is a linguistic phrase. Some examples of such linguistic phrases are: "A is more important than B", or "A is of the same importance as B", or "A is a little more important than B", and so on.

For instance, when system A is compared to system B then the decision-maker has determined that system A is between to be classified as "essentially more important" and "demonstrated more important" than system B. Thus, the corresponding comparison assumes the value of 6.

Please indicate the level of preference by choosing the most descriptive score (both value and direction) in the rubrics below.

Level 1

	Extremely more Important								Equally Important								Extremely more Important	
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Indirect Costs
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Direct Cost
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Work Zone Safety
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Direct Cost
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Work Zone Safety
Direct Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints

Direct Cost	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Customer Service

Direct Cost	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Work Zone Safety

Site Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Customer Service

Site Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Work zone Safety

Customer Service	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Work Zone Safety

Level 2

Schedule Constraints:

Resource Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Marine and Wildlife Constraints
Marine and Wildlife Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Calendar or Utility or RxR or Navigational Constraints
Resource Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Calendar or Utility or RxR or Navigational Constraints

Indirect Costs:

Loss of Revenue to Local Business	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Impact to Neighborhood Livability during Construction
Loss of Revenue to Local Business	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Costs of Users Delay
Loss of Revenue to Local Business	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Costs of Truckers Delay
Impact to Neighborhood Livability during Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Costs of Users Delay
Impact to Neighborhood Livability during Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Costs of Truckers Delay
Costs of Users Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Costs of Truckers Delay

Work zone Safety:

Safety Costs to Traveling Public	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Safety Costs to Construction Workers

Direct Cost:

MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Toll Revenue
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Right of Way Costs

MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Detour Costs
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development Costs
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Essential Services Maintenance Cost
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
MOT Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Right of Way Costs
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Detour Costs
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development Costs
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Essential Services Maintenance Cost
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs

Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
Toll Revenue	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Detour Costs
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development Costs
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Essential Services Maintenance Cost
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
Right of Way Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Detour Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development Costs
Detour Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Essential Services Maintenance Cost

Detour Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs
Detour Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
Detour Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Project Design and Development Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Essential Services Maintenance Cost
Project Design and Development Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs
Project Design and Development Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
Project Design and Development Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Essential Services Maintenance Cost	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Costs
Essential Services Maintenance Cost	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs

Essential Services Maintenance Cost	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Construction Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Agency Construction Management Costs
Construction Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs
Agency Construction Management Costs	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation Costs

Site Constraints:

Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Span Design
Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Archaeological Constraints
Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Historical Constraints
Span Design	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Archaeological Constraints
Span Design	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Historical Constraints

Archaeological Constraints	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Historical Constraints

Level 3

Calendar or Utility or RxR or Navigational Constraints:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Marine and Wildlife Constraints:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Resource Constraints:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Safety Costs to Traveling Public:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Safety Costs to Construction Workers:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Loss of Revenue to Local Business:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Impact to Neighborhood Livability during Construction:

Detour	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Realignment

Costs of Users Delay:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Costs of Truckers Delay:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Horizontal/Vertical Obstructions:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Span Design:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Archaeological Constraints:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Historical Constraints:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

MOT Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Toll Revenue:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Right of Way Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Detour Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Project Design and Development Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Essential Services Maintenance Cost:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Construction Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Agency Construction Management Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

Inspection, Maintenance and Preservation Costs:

Detour 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Realignment

APPENDIX F
FINAL CRITERIA LIST AND DEFINITIONS

High-level Criteria	Sub-Criteria	Definition
Direct Costs	Construction	This factor captures the estimated costs associated with the construction of the permanent structure(s) and roadway. This factor includes premiums associated with new technologies or innovative construction methods. Premiums might result from factors such as contractor availability, materials availability, and contractor risk. It may include incentive/bonus payments for early completion and other innovative contracting methods.
	Maintenance of Traffic (MOT)	This factor captures the maintenance of traffic costs at the project site. MOT costs may impact preference due to its impact on total costs. This factor includes all costs associated with the maintenance of detours before, during, and after construction. Examples of this factor include; Installation of traffic control devices, maintenance of detour during construction including flagging, shifting of traffic control devices during staged construction, restoration associated with the temporary detours upon completion of construction.
	Design and Construct Detours	This factor captures the costs to design and construct temporary structures and roadways to accommodate traffic through the project site.
	Right of Way (ROW)	This factor captures the cost to procure ROW. This factor includes either permanent or temporary procurements/easements.
	Project Design and Development	This factor captures the costs associated with the design of permanent bridge(s) and costs related to project development based on the construction method.
	Maintenance of Essential Services	This factor captures the costs associated with the need to provide essential services that may be impacted by the construction selected. Examples of this factor include alternate routes or modes of transportation to provide defense, evacuation, emergency access to hospitals, schools, fire station, and law enforcement, etc. This criterion is for situations where measures needed to be implemented beyond those already considered in the "MOT" and "Design and Construct Detours" criteria.
	Construction Engineering	This factor captures the costs associated with the owner's contract administration of the project.
	Inspection, Maintenance and Preservation	This factor captures the life cycle costs associated with the inspection, maintenance and preservation of individual bridge elements.
	Toll Revenue	This factor captures the loss of revenue due to the closure of a toll facility.
Indirect Costs	User Delay	This factor captures costs of user delay at a project site due to reduced speeds and/or off-site detour routes.
	Freight Mobility	This factor captures costs of freight delay at a project site due to reduced speeds and/or off-site detour routes.
	Revenue Loss	This factor captures lost revenues due to limited access to local business resulting from limited or more difficult access stemming from the construction activity.
	Livability During Construction	This factor captures the impact to the communities resulting from construction activities. Examples include noise, air quality, and limited access.
	Road Users Exposure	This factor captures the safety risks associated with user exposure to the construction zone.
	Construction Personnel Exposure	This factor captures the safety risks associated with worker exposure to construction zone.

High-level Criteria	Sub-Criteria	Definition
Schedule Constraints	Calendar or Utility or RR or Navigational	This factor captures the constraints placed on the project that might affect the timing of construction as a result of weather windows, significant or special events, railroad, or navigational channels.
	Marine and Wildlife	This factor captures the constraints placed on the project by resource agencies to comply with marine or wildlife regulations. Examples include in-water work windows, migratory windows, and nesting requirements.
	Resource Availability	This factor captures resource constraints associated with the availability of staff to design and oversee construction. For example, a state may be required to outsource a project, which may result in additional time requirements.
Site Constraints	Bridge Span Configurations	This factor captures constraints related to bridge span configurations. This element may impact owner preference regarding bridge layout, structure type, or aesthetics.
	Horizontal/Vertical Obstructions	This factor captures physical constraints that may impact construction alternatives. Examples include bridges next to fixed objects such as tunnels, ROW limitations, sharp curves or steep grades, or other urban area structures that constrain methods and/or bridge locations.
	Environmental	This factor captures the constraints placed on the project by resource agencies to minimize construction impacts on natural resources including marine, wildlife, and flora.
	Historical	This factor captures historical constraints existing on a project site.
	Archaeological Constraints	This factor captures archaeological constraints existing on a project site.
Customer Service	Public Perception	This factor captures both the public's opinion regarding the construction progress and their overall level of satisfaction.
	Public Relations	This factor captures the costs associated with the communication and management of public relations before and during construction.

APPENDIX G
FINAL AHP PAPER SURVEY

Please indicate the level of preference by choosing the most descriptive score (both value and direction) in the rubrics below.

Level 1

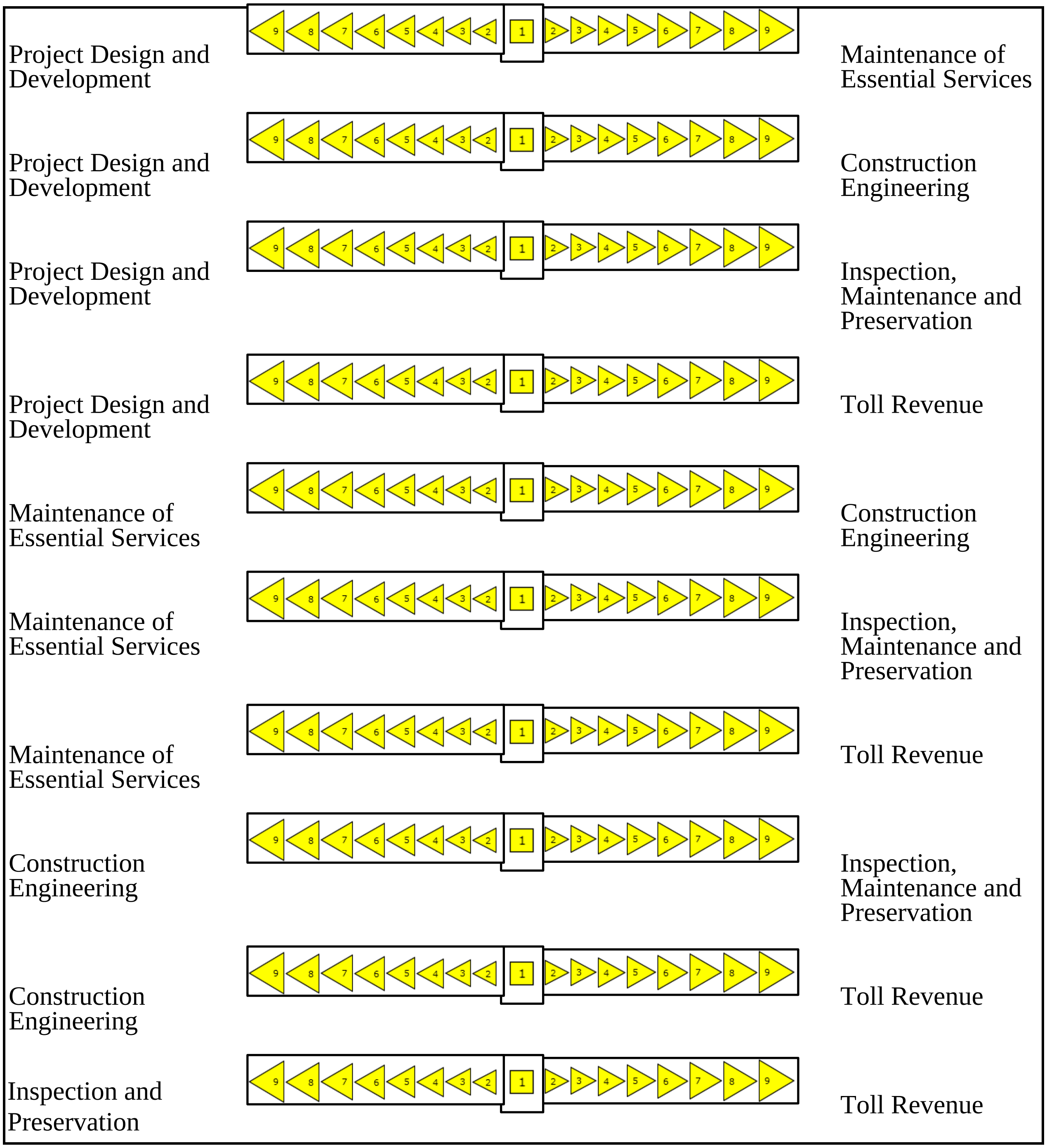
	Extremely more Important								Equally Important								Extremely more Important	
Direct Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Indirect Costs
Direct Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Schedule Constraints
Direct Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints
Direct Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Schedule Constraints
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints
Indirect Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Site Constraints
Schedule Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service
Site Constraints	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Customer Service

Level 2

Direct Costs:

Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	MOT
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Design and Construct Detours
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Right of Way
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Maintenance of Essential Services
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Engineering
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation
Construction	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Toll Revenue
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Design and Construct Detours
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Right of Way
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Maintenance of Essential Services
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Engineering

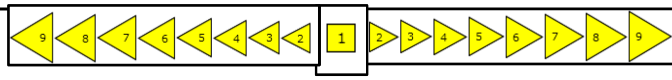
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation
MOT	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Toll Revenue
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Right of Way
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Maintenance of Essential Services
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Engineering
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation
Design and Construct Detours	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Toll Revenue
Right of Way	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Project Design and Development
Right of Way	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Maintenance of Essential Services
Right of Way	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Engineering
Right of Way	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Inspection, Maintenance and Preservation
Right of Way	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Toll Revenue


Project Design and Development
9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9
Maintenance of Essential Services
Project Design and Development
Construction Engineering
Project Design and Development
Inspection, Maintenance and Preservation
Project Design and Development
Toll Revenue
Maintenance of Essential Services
Construction Engineering
Maintenance of Essential Services
Inspection, Maintenance and Preservation
Maintenance of Essential Services
Toll Revenue
Construction Engineering
Inspection, Maintenance and Preservation
Construction Engineering
Toll Revenue
Inspection and Preservation
Toll Revenue

Indirect Costs:

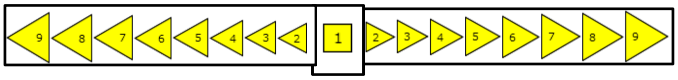
User Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Freight Mobility
User Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Revenue Loss
User Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Livability During Construction
User Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Road Users Exposures
User Delay	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Personnel Exposure
Freight Mobility	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Revenue Loss
Freight Mobility	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Livability During Construction
Freight Mobility	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Road Users Exposures
Freight Mobility	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Personnel Exposure
Revenue Loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Livability During Construction
Revenue Loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Road Users Exposures
Revenue Loss	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Construction Personnel Exposure

Livability During Construction



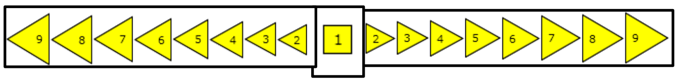
Road Users Exposures

Livability During Construction



Construction Personnel Exposure

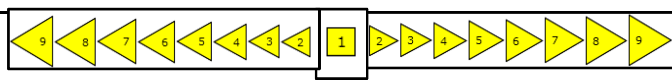
Road User Exposure



Construction Personnel Exposure

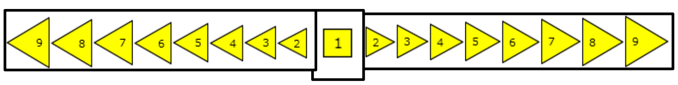
Schedule Constraints:

Calendar or Utility orRxR or Navigational



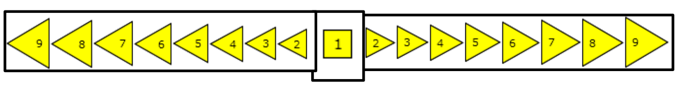
Marine and Wildlife

Calendar or Utility orRxR or Navigational



Resource Availability

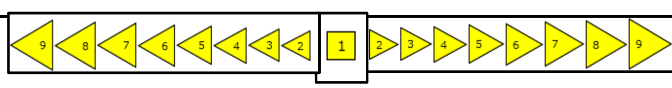
Marine and Wildlife



Resource Availability

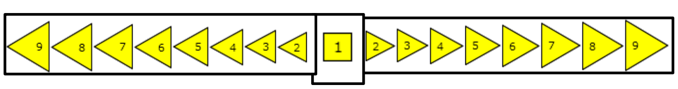
Site Constraints:

Bridge Span Configurations



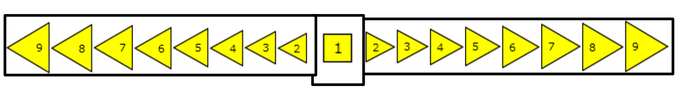
Horizontal/ Vertical Obstructions

Bridge Span Configurations



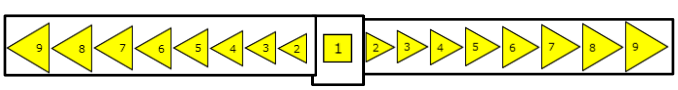
Environmental

Bridge Span Configurations



Historical

Bridge Span Configurations



Archaeological Constraints

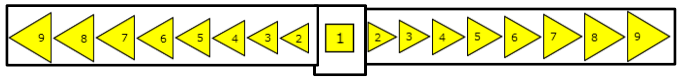
Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Environmental
Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Historical
Horizontal/Vertical Obstructions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Archaeological Constraints
Environmental	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Historical
Environmental	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Archaeological Constraints
Historical	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Archaeological Constraints

Customer Service:

Public Perceptions	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Public Relations

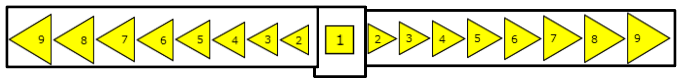
Level 3

Construction:

ABC 

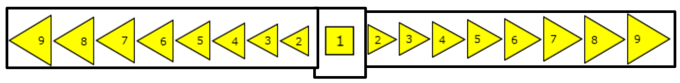
Conventional

Maintenance of Traffic (MOT):

ABC 

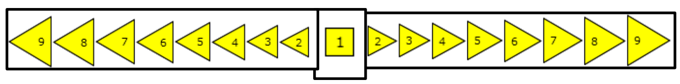
Conventional

Design and Construct Detours:

ABC 

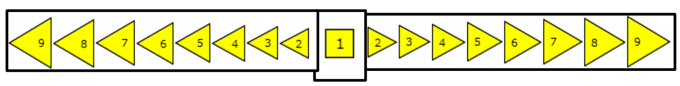
Conventional

Right of Way (ROW):

ABC 

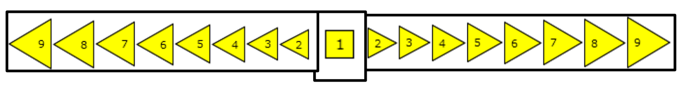
Conventional

Project Design and Development:

ABC 

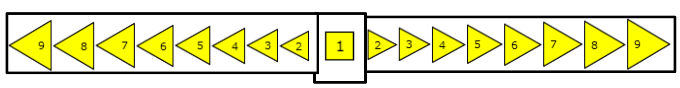
Conventional

Maintenance of Essential Services:

ABC 

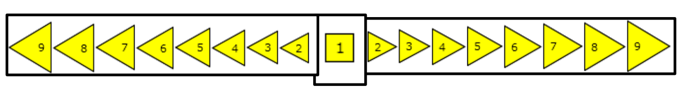
Conventional

Construction Engineering:

ABC 

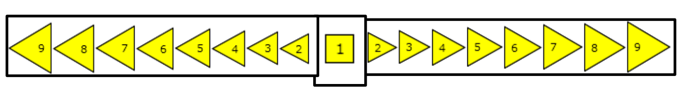
Conventional

Inspection, Maintenance and Preservation:

ABC 

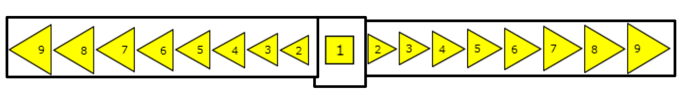
Conventional

Toll Revenue:

ABC 

Conventional

User Delay:

ABC 

Conventional

Freight Mobility:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Revenue Loss:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Livability During Construction:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Road Users Exposure:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Construction Personnel Exposure:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Calendar or Utility or RxR or Navigational:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Marine and Wildlife:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Resource Availability:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

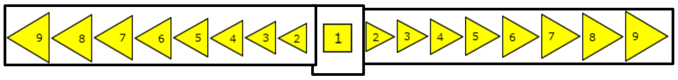
Bridge Span Configurations:

ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Horizontal/Vertical Obstructions:

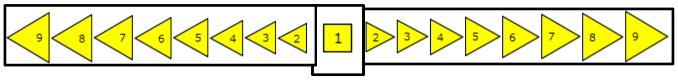
ABC 9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9 Conventional

Environmental:



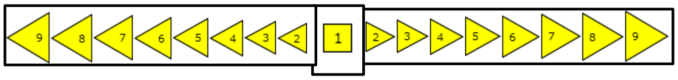
ABC Conventional

Historical:



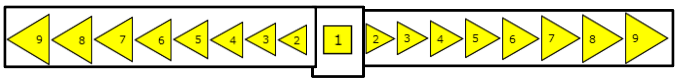
ABC Conventional

Archaeological Constraints:



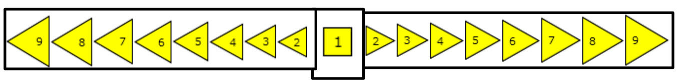
ABC Conventional

Public Perception:



ABC Conventional

Public Relations:



ABC Conventional

APPENDIX H
AHP ANALYSIS REPORTS

U.S. 6 over Keg Creek in Pottawattamie County, Iowa

The proposed improvements consist of replacing the bridge located on US 6 over Keg Creek in Pottawattamie County, Iowa. The existing 180 foot x 28 foot continuous concrete girder bridge was constructed in 1953 and is currently classified as structurally deficient with sufficiency rating of 33. The proposed bridge replacement is intended to increase the structural capacity of the bridge, improve roadway conditions, and enhance safety by providing a wider roadway.

Construction zone safety will be greatly improved due to the introduction of innovative accelerated bridge construction (ABC) methods (limit traffic interference to a period of two weeks or less). Furthermore, by minimizing the need for future maintenance that interferes with traffic flow, congestion and crashes will be reduced.

The replacement structure will be a three-span (67’-3”, 70’-0”, 67’-3”) 210’-2” x 47’-2” Steel/Precast Modular Bridge with precast bridge approaches.

This accelerated project will limit the construction time to a maximum of two-week road closure. It is estimated that the construction time would have been six months under non-accelerated construction procedures.

A Demonstration of Using ABC Decision Making Software for Keg Creek Project

This report summarizes the AHP analysis for the Keg Creek project. The required data for this analysis was provided by Iowa Department of Transportation. In this study, two construction alternatives are compared: ABC Modular Bridge (all components are prefabricated off site) and a traditional bridge (Conventional). Both alternatives are on the same alignment with off-site detour.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the Modular Bridge (ABC) alternative is preferable over the Conventional alternative for the project. The calculated utilities for the Modular and Convectional alternatives are 0.679 and 0.323, respectively.

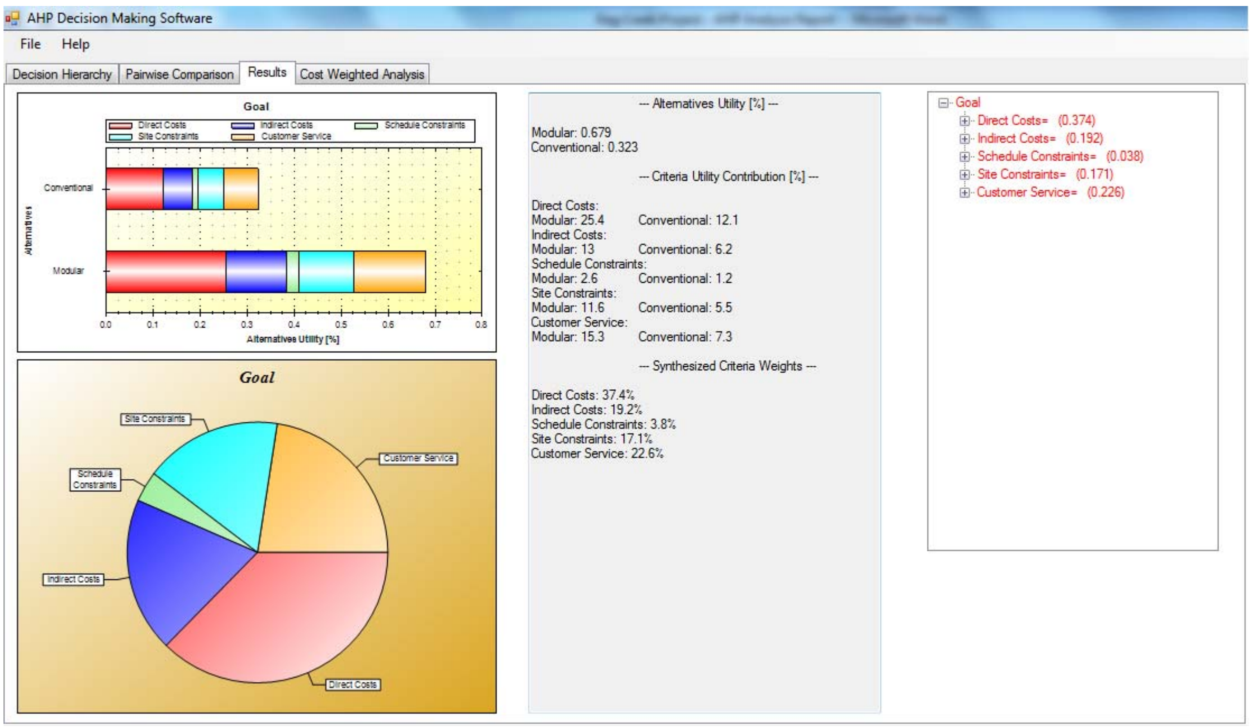


Figure 1: ABC Decision Making Software Output for the Keg Creek Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

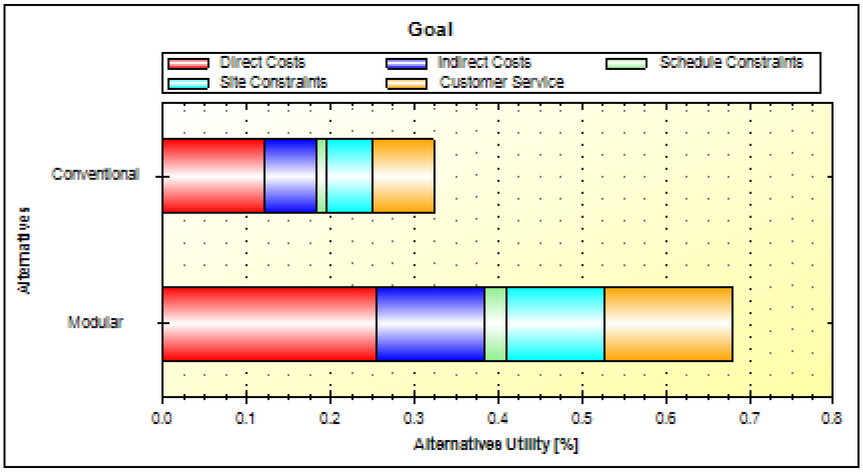


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Keg Creek project. The results indicate that "Direct Costs" and "Customer Service" have the greatest impact on the decision to choose Modular Bridge as the suitable alternative.

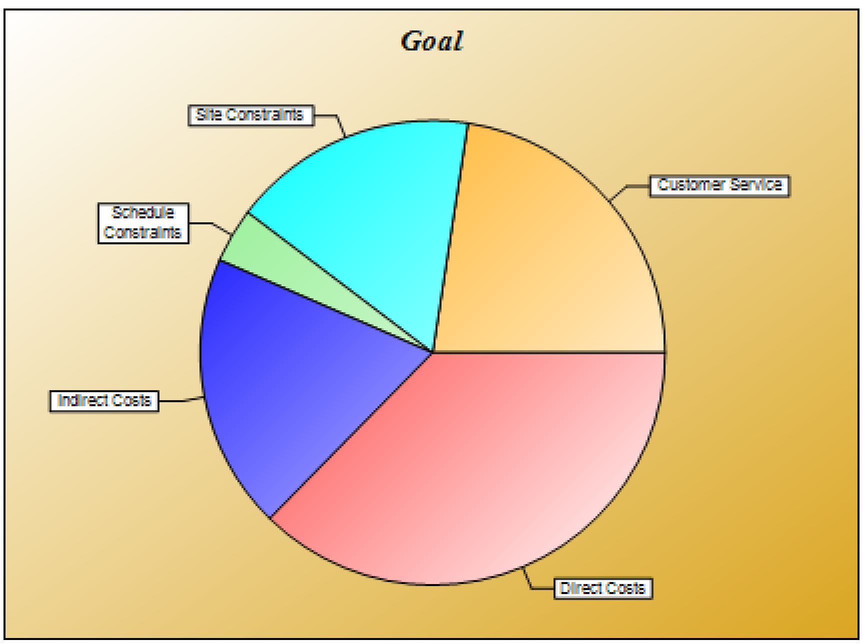


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (Modular or Conventional) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

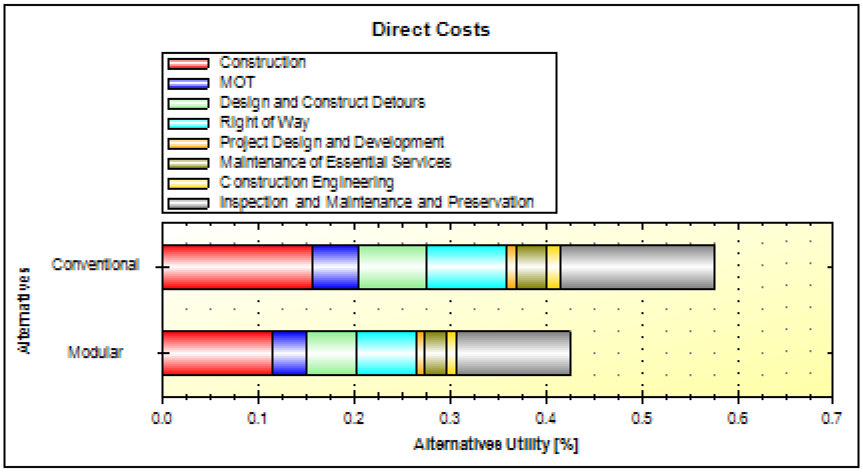


Figure 4: Ranks for Direct Costs

Figures 4 and 5 summarize the results for the “Direct Costs” category. Figure 4 shows that the Conventional alternative is preferred when only direct costs criteria are considered. Figure 5 highlights that “Inspection, Maintenance, and Preservation” and “Construction” criteria are the most important contributors to this preference.

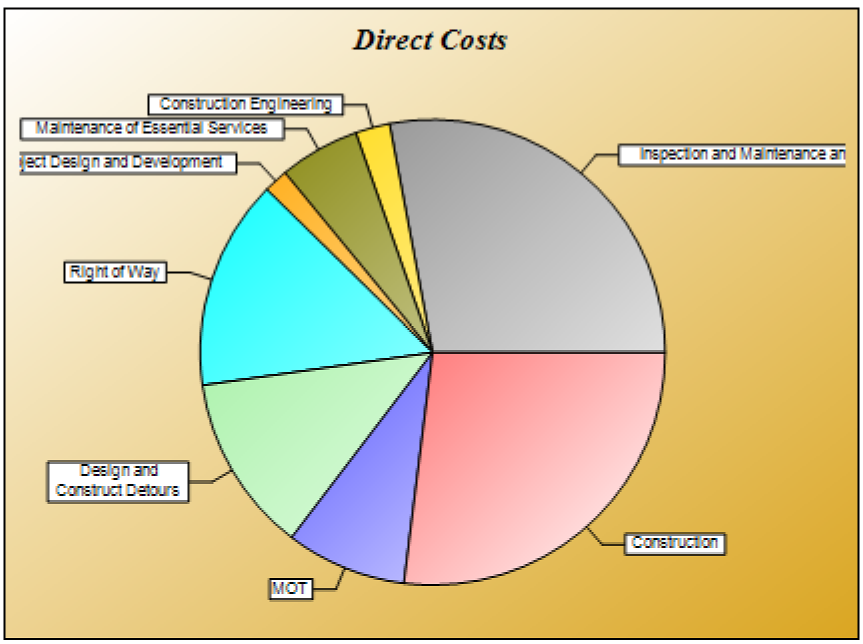


Figure 5: Sub-Criteria Weights for Direct Costs

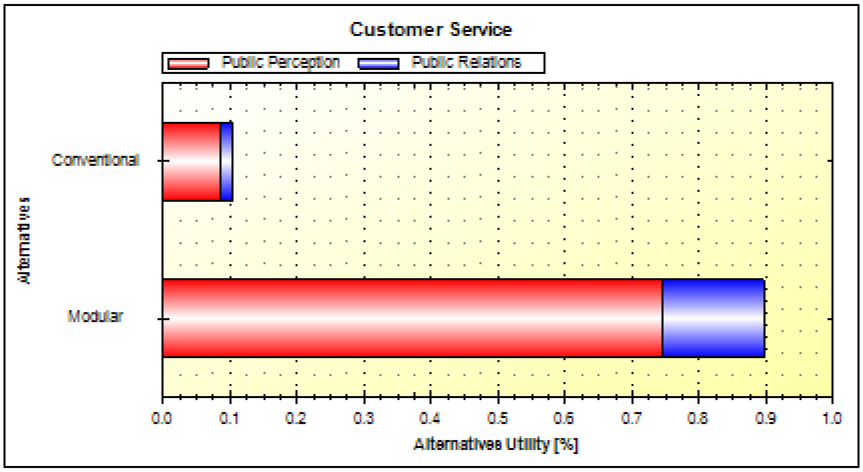


Figure 6: Ranks for Customer Service

Figures 6 and 7 summarize the results for the "Customer Service" category. Figure 6 indicates that the Modular alternative is highly preferred over the Conventional method on the basis of customer service. In Figure 7, it is highlighted that "Public Reception" has the greatest impact on this preference.

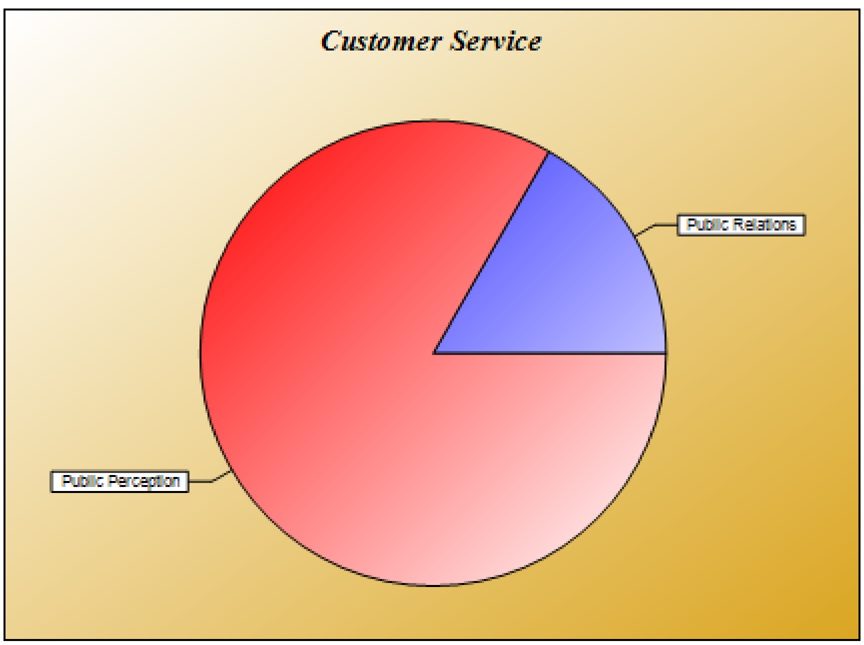


Figure 7: Sub-Criteria Weights for Customer Service

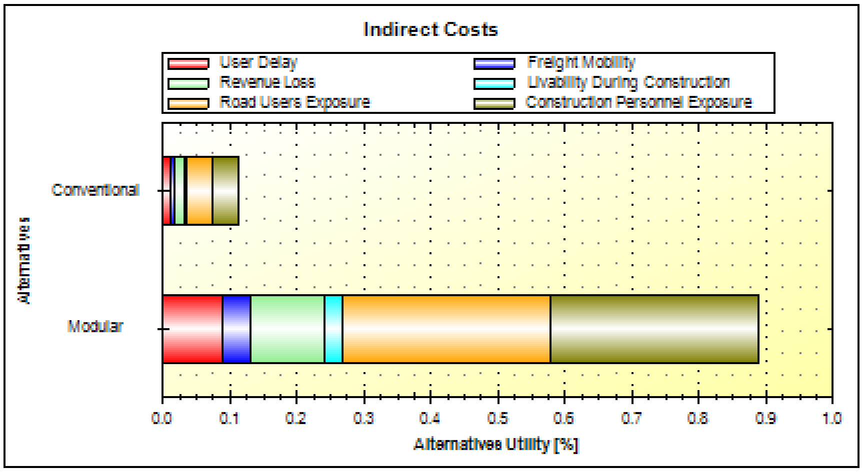


Figure 8: Ranks for Indirect Costs

The analysis results related to the "Indirect Costs" category are shown in Figures 8 and 9. In Figure 8, the amount of contribution of six sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that "Road Users Exposure" and "Construction Personnel Exposure" are the two sub-criteria with the highest weight in the indirect costs category.

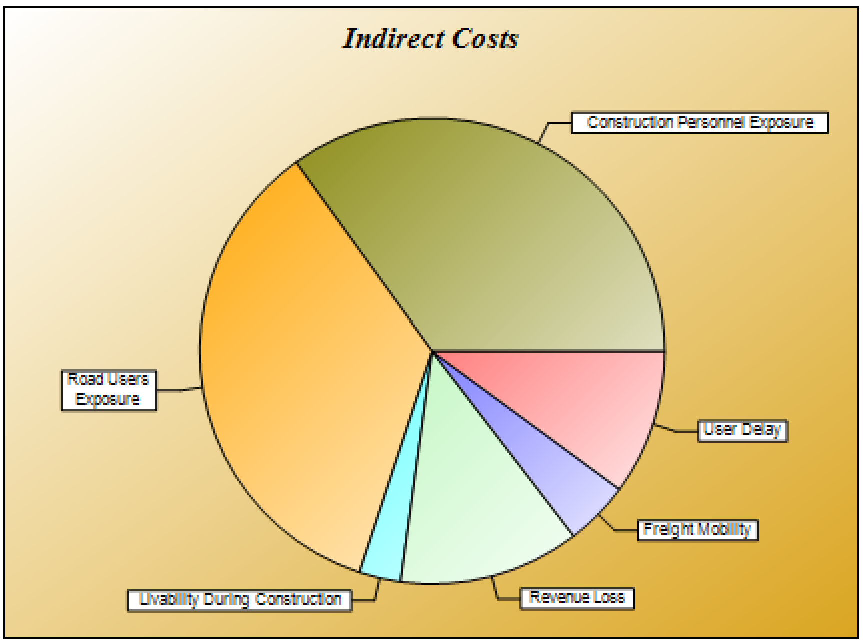


Figure 9: Sub-Criteria Weights for Indirect Costs

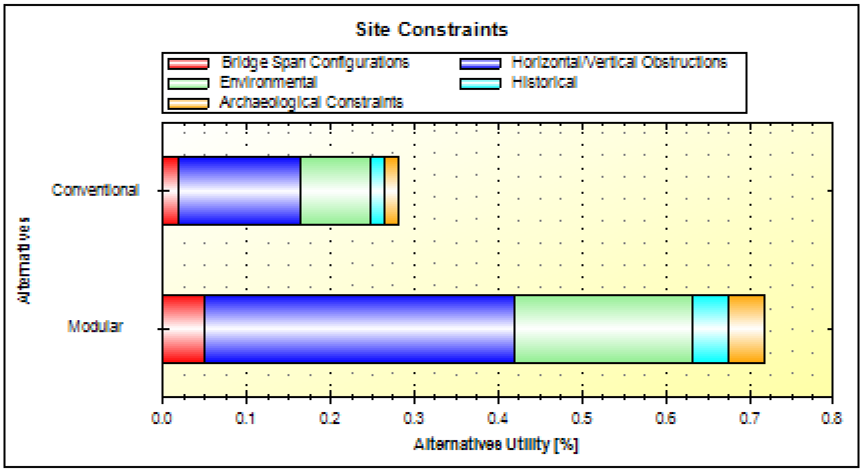


Figure 10: Ranks for Site Constraints

Figures 10 and 11 summarize the results for the "Site Constraints" category. Figure 10 indicates the alternatives utility with regard to this high-level criterion. Figure 11 highlights that "Horizontal/Vertical Obstructions" and "Environmental Factors" have the greatest influence on the preference for Modular alternative over Conventional method in the site constraints category.

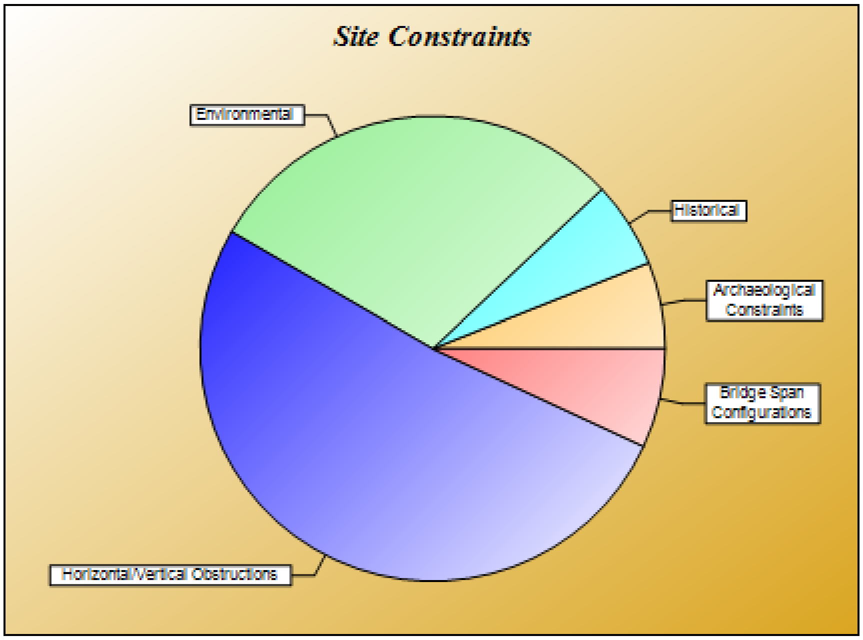


Figure 11: Sub-Criteria Weights for Site Constraints

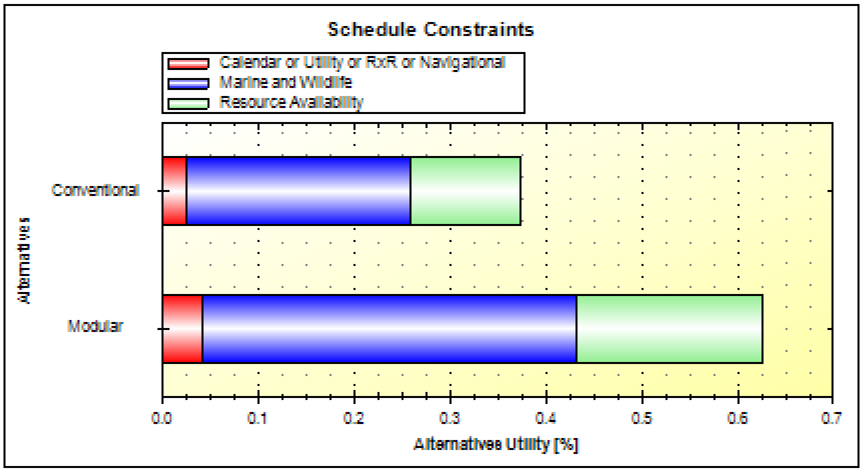


Figure 12: Ranks for Schedule Constraints

The last high-level criterion is “Schedule Constraints”. The details of this analysis are shown in Figures 12 and 13. Figure 12 shows that the Modular alternative is preferred when only schedule constraints criteria are considered. Figure 13 highlights that “Marine and Wildlife” criterion is the most important contributor to this preference.

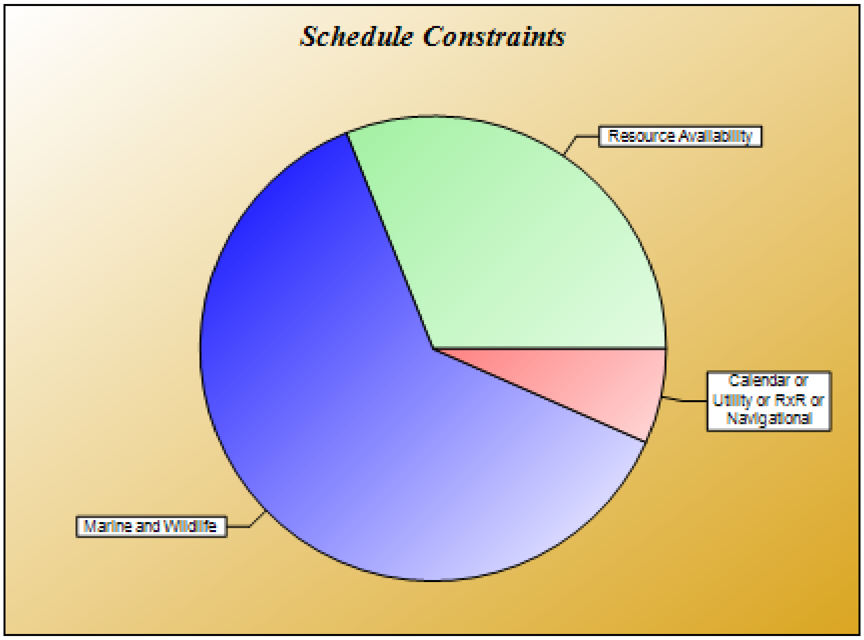


Figure 13: Criteria Weights for Schedule Constraints

U.S. 52 Bridge over the Mississippi River Overflow in Sabula, Iowa

This is a 342 foot by 20 foot steel high truss structure. The deck of the approach spans was replaced in 1985. The bridge is functionally obsolete due to the inadequate roadway width. This bridge is fracture critical and has many areas of section loss in the steel members. The substructure is susceptible to scour and has a scour monitoring plan. There is a large scour hole 50 feet downstream. The truss portals have sustained severe collision damage over the years. There is no rehabilitation option for correcting the narrow width or the low clearance problems. Therefore, this bridge is being replaced.

A Demonstration of Using ABC Decision Making Software for Sabula Bridge Project

This report summarizes the AHP analysis for the Sabula Bridge project. The required data for this analysis was provided by Iowa Department of Transportation. In this study, two construction alternatives are compared: same alignment with detour (ABC) and shifted alignment (Conventional).

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the same alignment with detour (ABC) is preferable over the shifted alignment alternative for the project. The calculated utilities for the same and shifted alignment alternatives are 0.727 and 0.274, respectively.

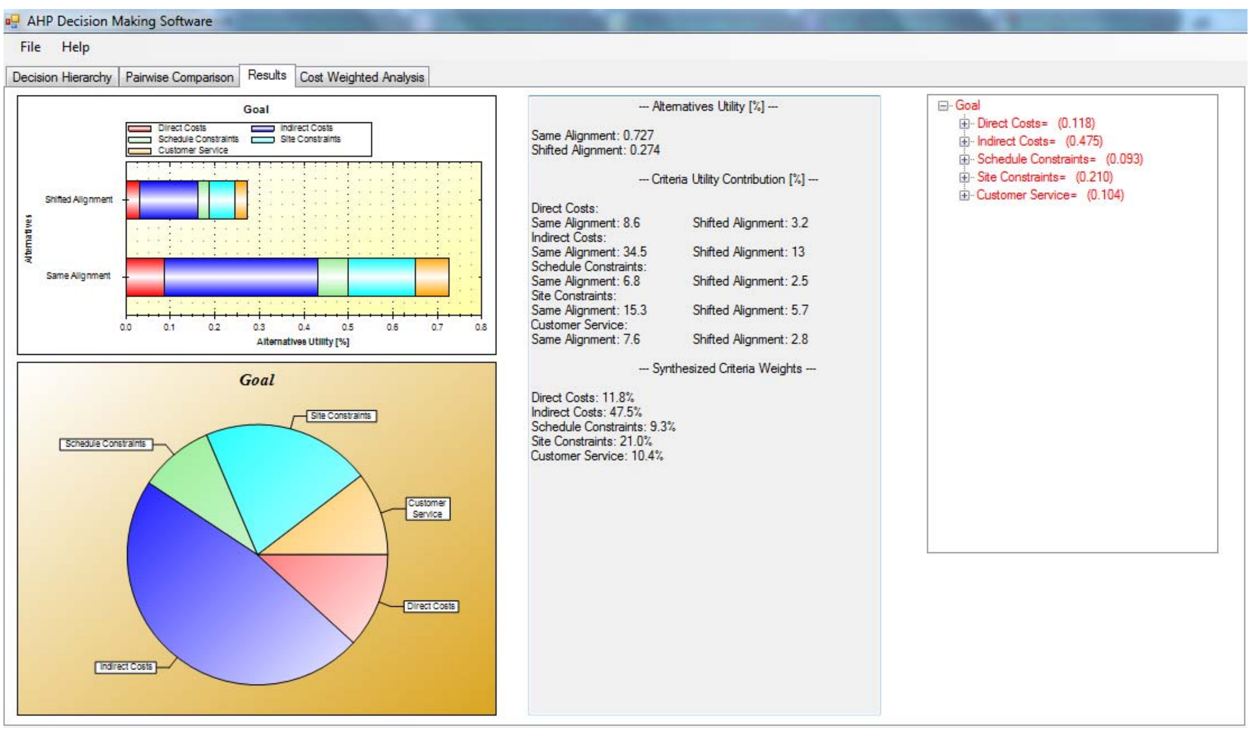


Figure 1: ABC Decision Making Software Output for the Sabula Bridge Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

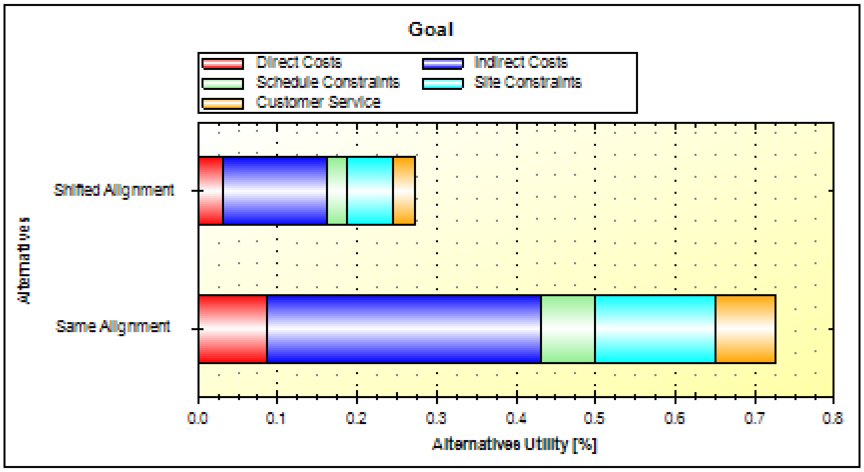


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Sabula Bridge project. The results indicate that “Indirect Costs” and “Site Constraints” have the greatest impact on the decision to choose the same alignment as the suitable alternative.

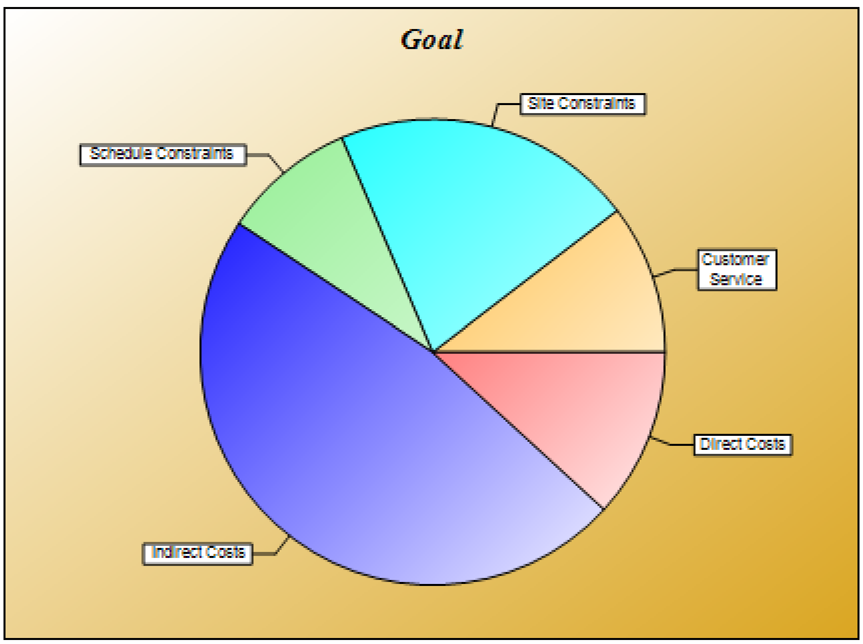


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (same or shifted alignment) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

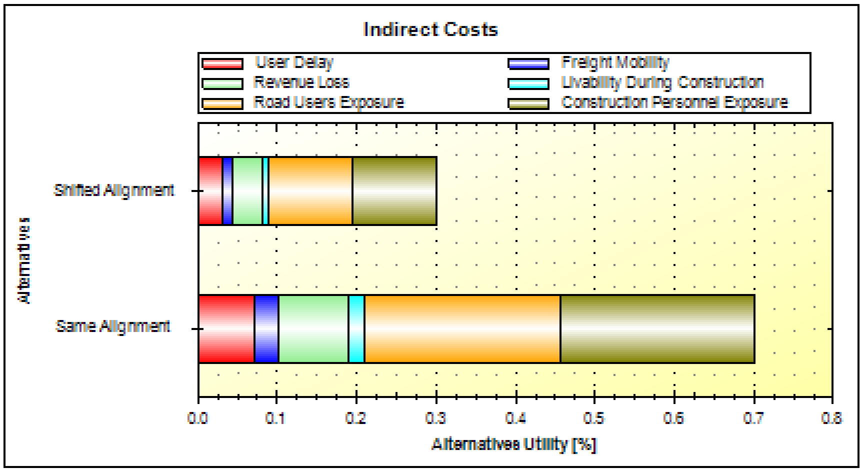


Figure 4: Ranks for Indirect Costs

Figures 4 and 5 summarize the results for the "Indirect Costs" category. Figure 4 shows that the same alignment alternative is preferred when only Indirect Costs criteria are considered. Figure 5 highlights that the two criteria with the highest influence on this preference include "Construction Personnel Exposure" and "Road Users Exposure".

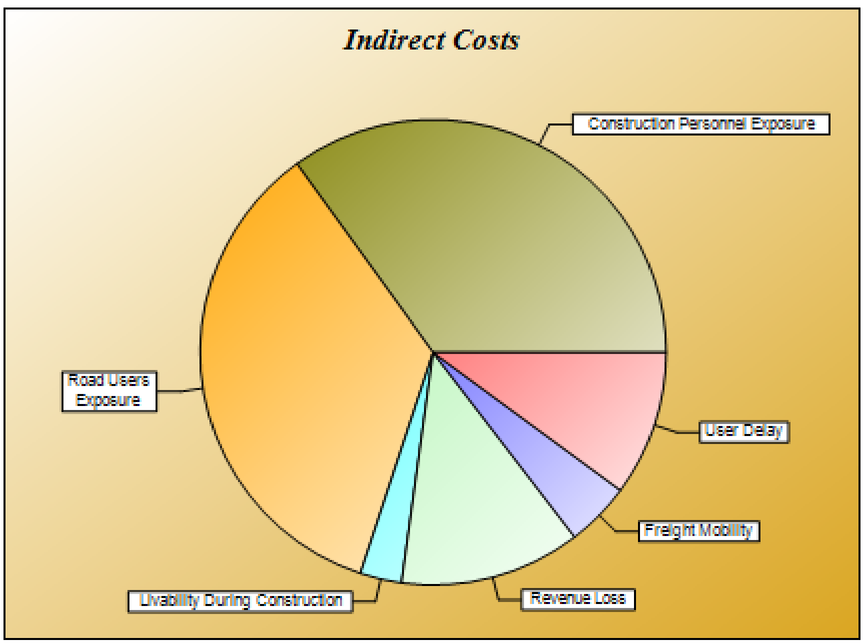


Figure 5: Sub-Criteria Weights for Indirect Costs

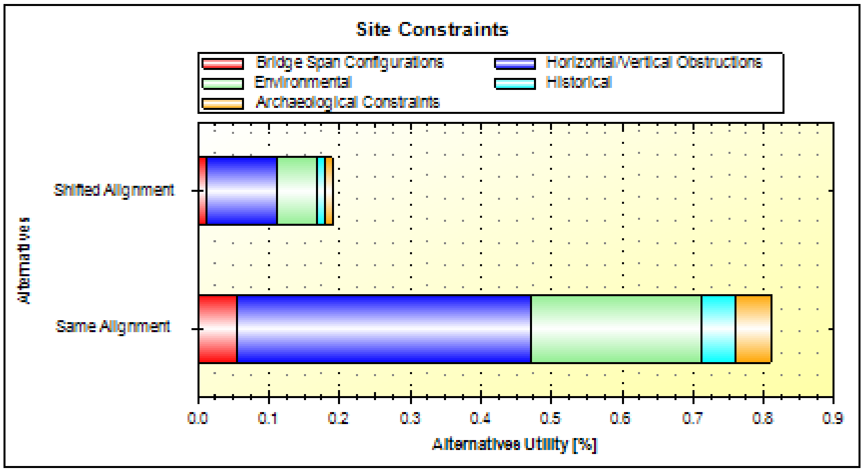


Figure 6: Ranks for Site Constraints

Figures 6 and 7 summarize the results for the "Site Constraints" category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 6 highlights that "Horizontal/Vertical Obstructions" and "Environmental Factors" have the greatest influence on the preference for the same alignment over the shifted alignment in the site constraints category.

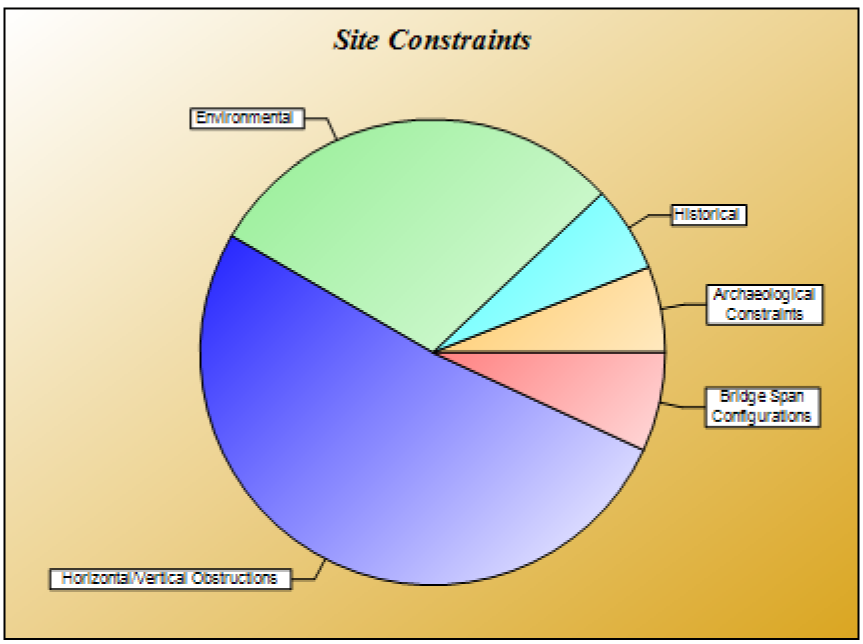


Figure 7: Sub-Criteria Weights for Site Constraints

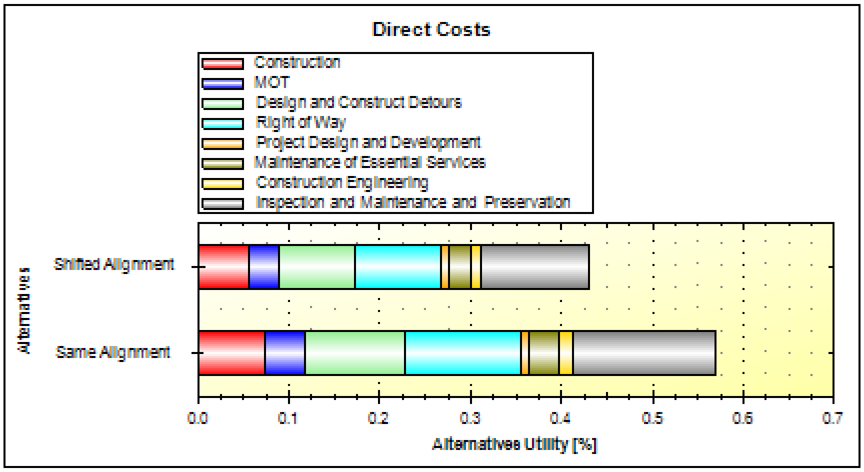


Figure 8: Ranks for Direct Costs

The analysis results related to the "Direct Costs" category are shown in Figures 8 and 9. In Figure 8, the amount of contribution of eight sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that "Inspection, Maintenance, and Preservation" and "Right of Way" are the two sub-criteria with the highest weight in the direct costs category.

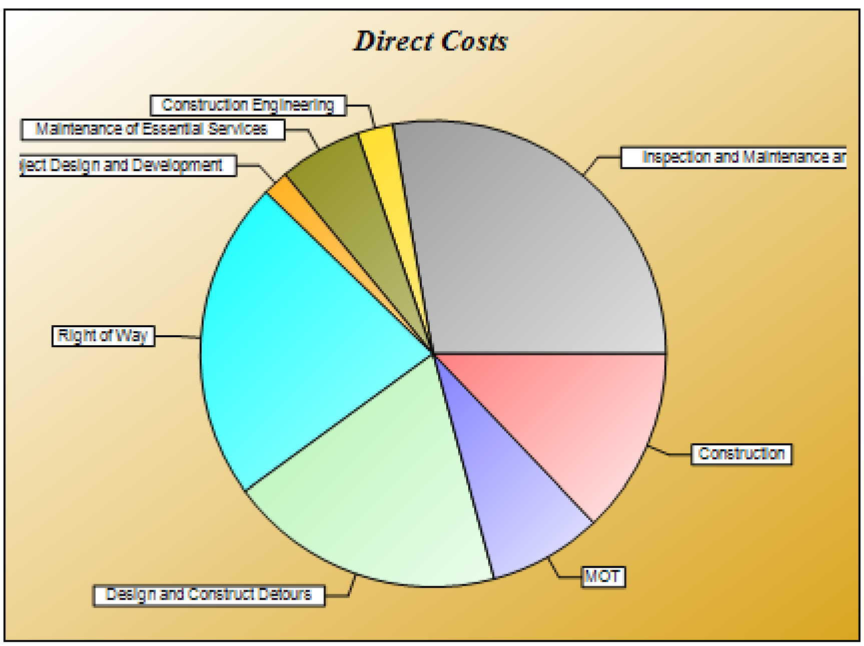


Figure 9: Sub-Criteria Weights for Direct Costs

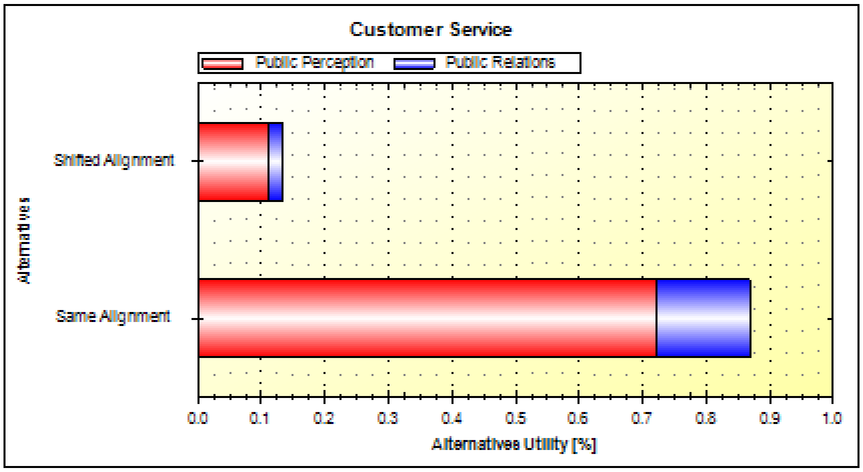


Figure 10: Ranks for Customer Service

Figures 10 and 11 summarize the results for the "Customer Service" category. Figure 10 indicates that the same alignment alternative is highly preferred over the shifted alignment on the basis of customer service. In Figure 11, it is highlighted that "Public Perception" has the greatest impact on this preference.

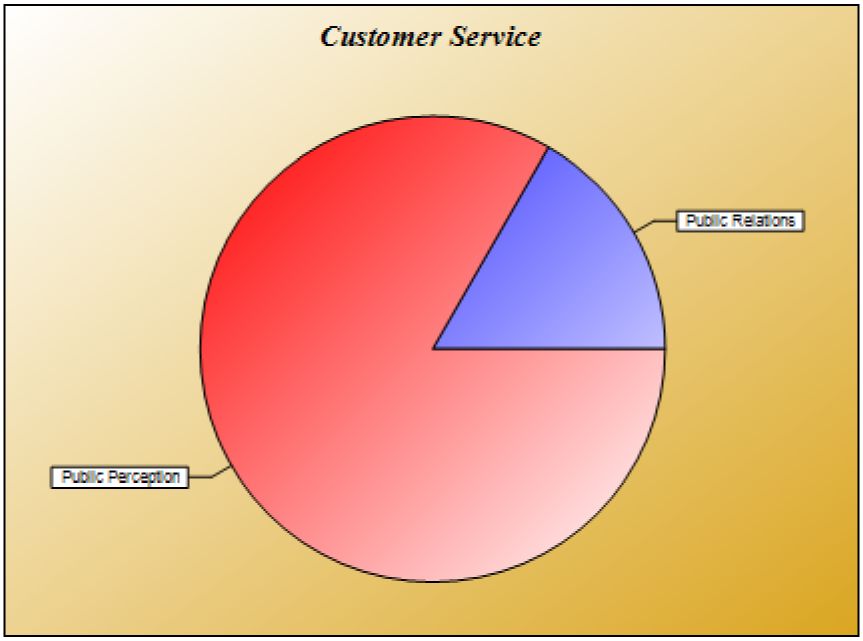


Figure 11: Sub-Criteria Weights for Customer Service

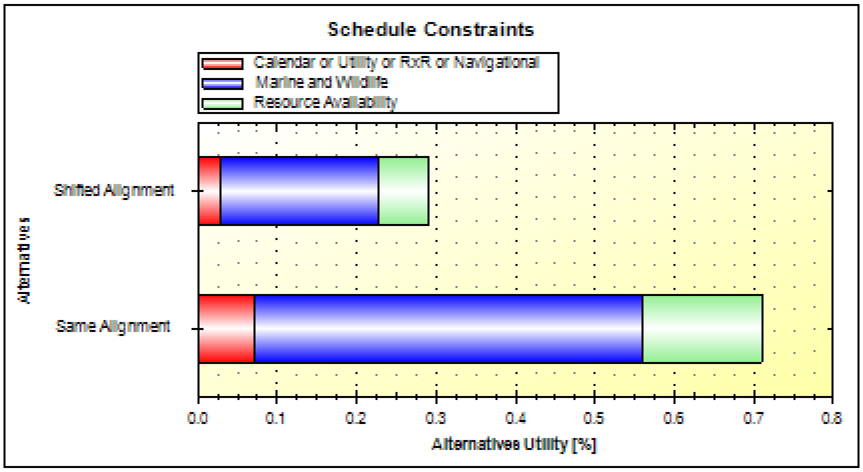


Figure 12: Ranks for Schedule Constraints

The last criterion with the lowest priority among the high-level criteria is "Schedule Constraints". The details of the analysis related to this criterion are shown in Figures 12 and 13. As it is indicated, the same alignment alternative is preferable over the shifted alignment in this category as well. In Figure 13, it is highlighted that "Marine and Wildlife" has the greatest impact on this preference.

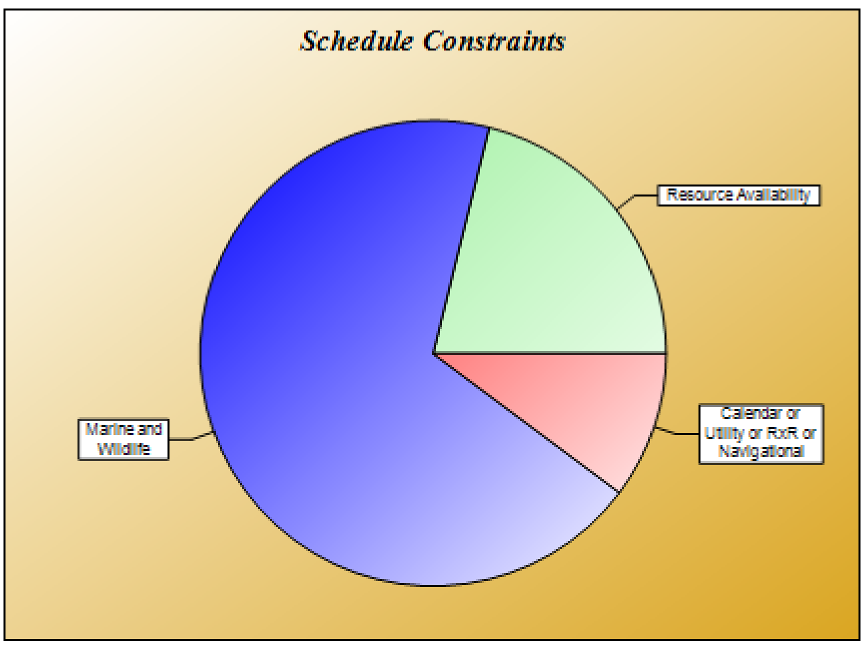


Figure 13: Sub-Criteria Weights for Schedule Constraints

Custer Interchange Project in Montana

This project is intended to implement a portion of the improvements in the preferred and selected alternative included in the interstate 15 corridor final environmental impact statement (FEIS) and Record of Decision (ROD). The improvements include reconstruction of Custer Avenue to provide four lanes, median turn lanes, and a bike/pedestrian envelope on both sides of Custer Avenue; accommodations for four lanes to Interstate 15 through the project corridor; various improvements to roads and streets around the project in anticipation of heavier traffic volumes during and after construction of the interchange. The total project length, including ramps and both sides of the affected interstate, is 5.28 miles. The current ADT on Custer Avenue is 15000. The design ADT is 41000.

The project is located within the urban limits of Helena in a developing commercial district that had no growth policy. There were few right of way constraints, but negotiations with landowners adjacent to the project were expected to be difficult. Meetings with business owners on Custer Avenue indicated their primary concern with project was lost revenue due to limited customer access during construction.

A Demonstration of Using ABC Decision Making Software for Custer Interchange Project

This report summarizes the AHP analysis for the Custer Interchange project. The required data for this analysis was provided by Montana Department of Transportation. In this study, two construction alternatives are compared: Pre-Cast Elements (PCE), and Phase Construction, which is the conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the PCE alternative is highly preferable over the Phase Construction alternative for this project. The calculated utilities for the PCE and Conventional alternatives are 0.699 and 0.301, respectively.

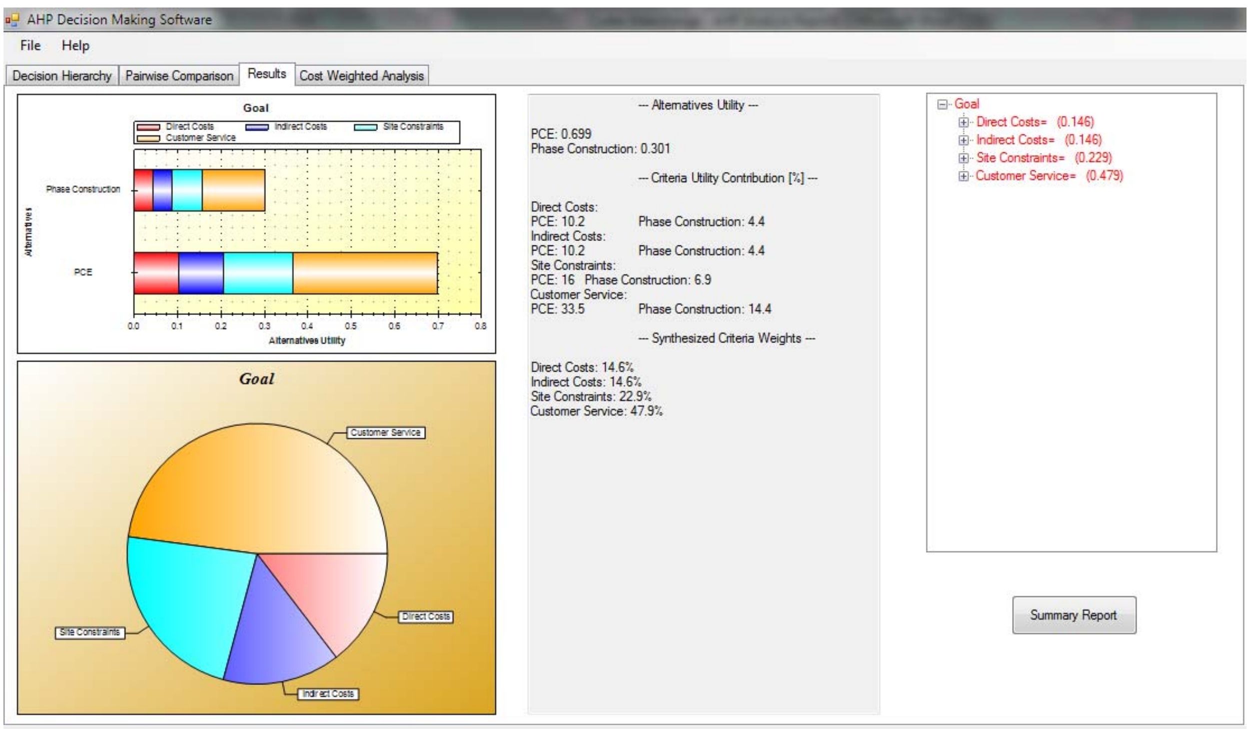


Figure 1: ABC Decision Making Software Output for the Custer Interchange Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

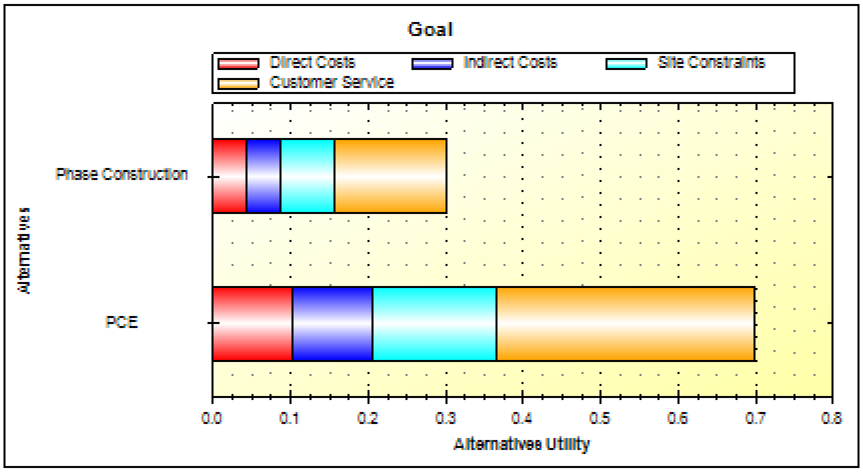


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Custer Interchange project. The results indicate that "Customer Service" and "Site Constraints" have the greatest impact on the decision to choose PCE as the suitable alternative.

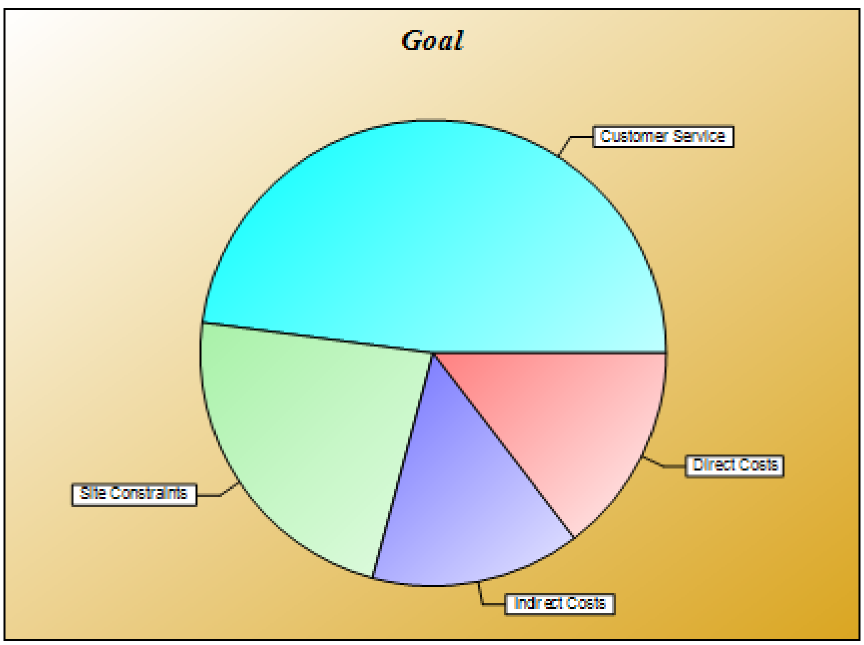


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (PCE or Phase Construction) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

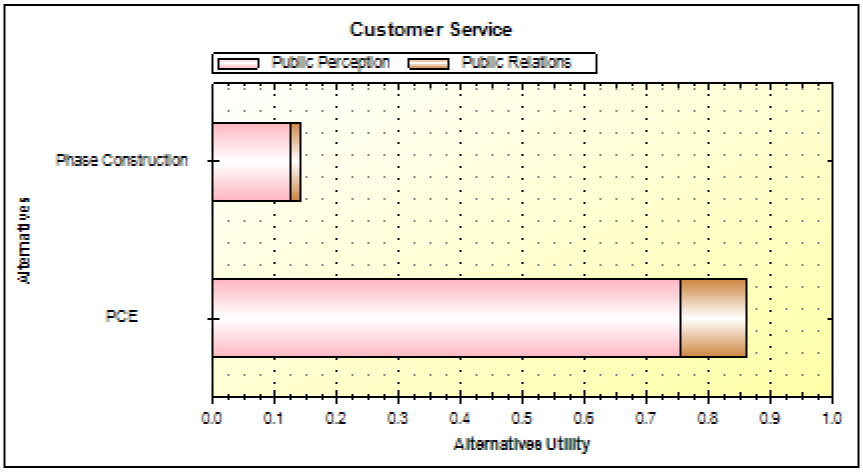


Figure 4: Ranks for Customer Service

Figures 4 and 5 summarize the results for the "Customer Service" category, which is the high-level criterion with the greatest priority. Figure 4 shows that the PCE alternative is highly preferred when only Customer Service criteria are considered. In Figure 5, it is highlighted that "Public Perception" has the greatest impact on this preference.

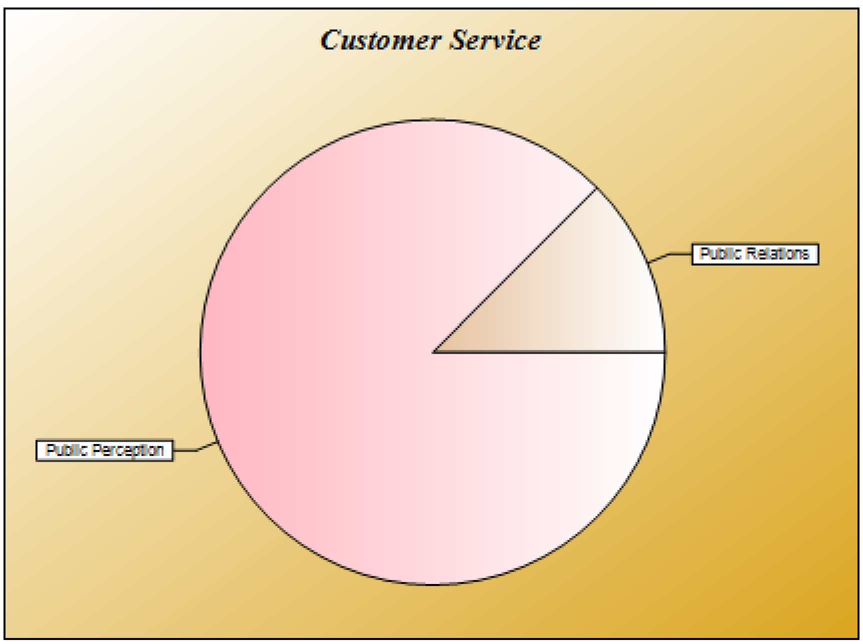


Figure 5: Sub-Criteria Weights for Customer Service

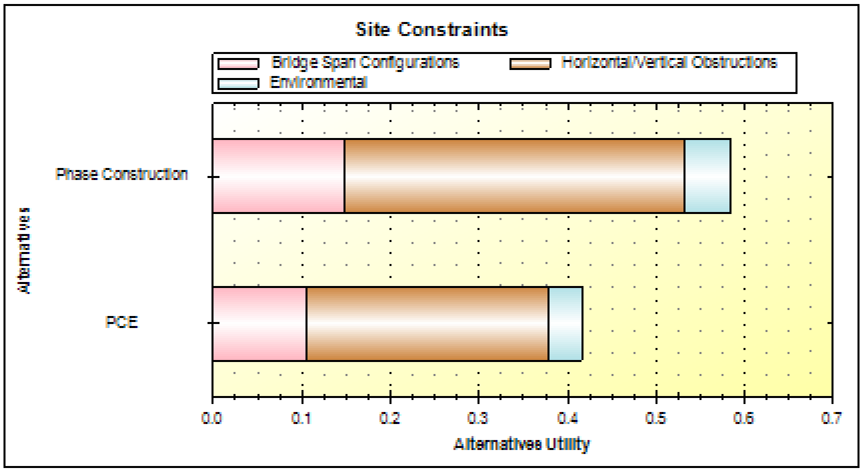


Figure 6: Ranks for Site Constraints

Figures 6 and 7 summarize the results for the "Site Constraints" category. Figure 6 indicates the alternatives utility with regard to this high-level criterion. As it is indicated, in this category, the Conventional method is preferred over PCE. Figure 7 highlights that "Horizontal/Vertical Obstructions" criterion has the greatest influence on this preference in the site constraints category.

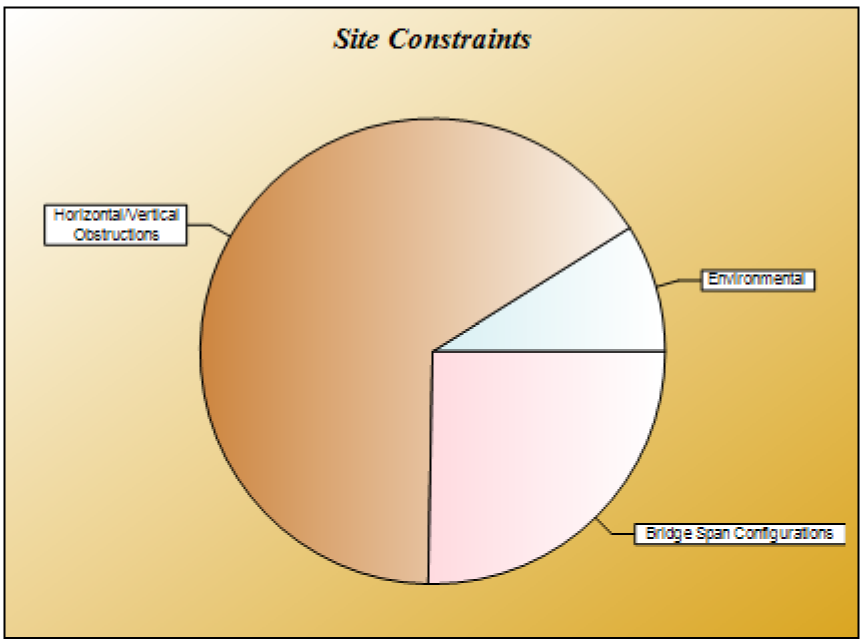


Figure 7: Criteria Weights for Site Constraints

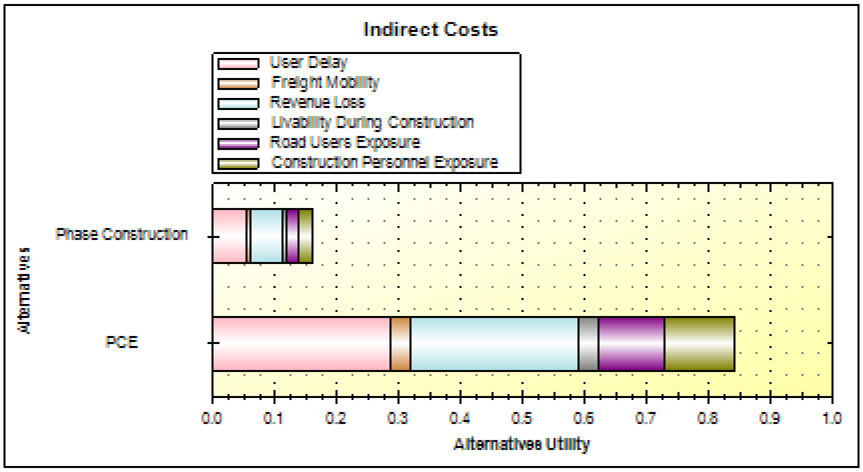


Figure 8: Ranks for Indirect Costs

Figures 8 and 9 summarize the results for the "Indirect Costs" category. In Figure 8, the amount of contribution of six sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that "User Delay" and "Revenue Loss" are the two sub-criteria with the highest weight in the indirect costs category.

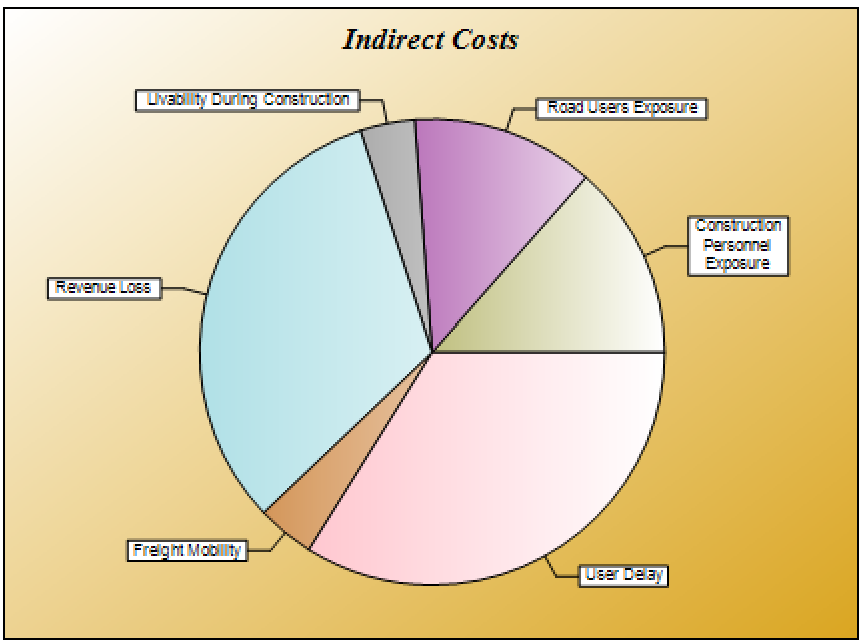


Figure 9: Sub-Criteria Weights for Indirect Costs

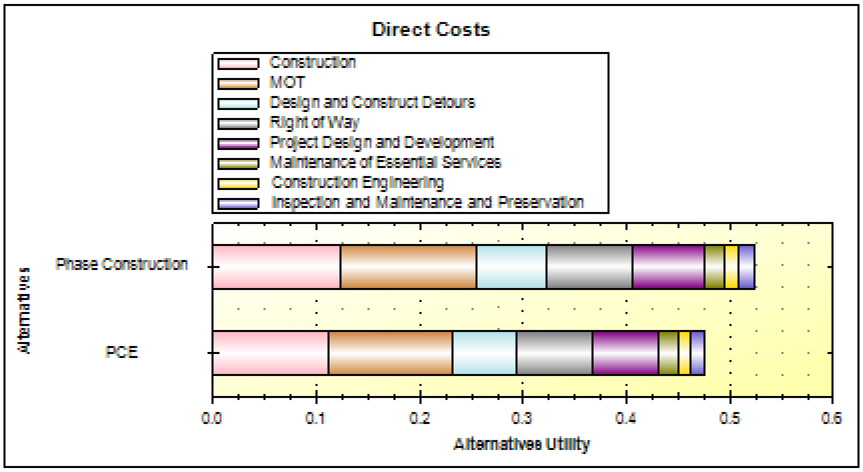


Figure 10: Ranks for Direct Costs

The last criterion with the lowest priority among the high-level criteria is "Direct Costs". The details of the analysis related to this criterion are shown in Figures 10 and 11. As it is indicated, Direct Costs is the other category in which the Phase Construction method is slightly preferred over the PCE alternative. In Figure 11, it is highlighted that "Maintenance of Traffic" and "Construction" have the greatest impact on this preference.

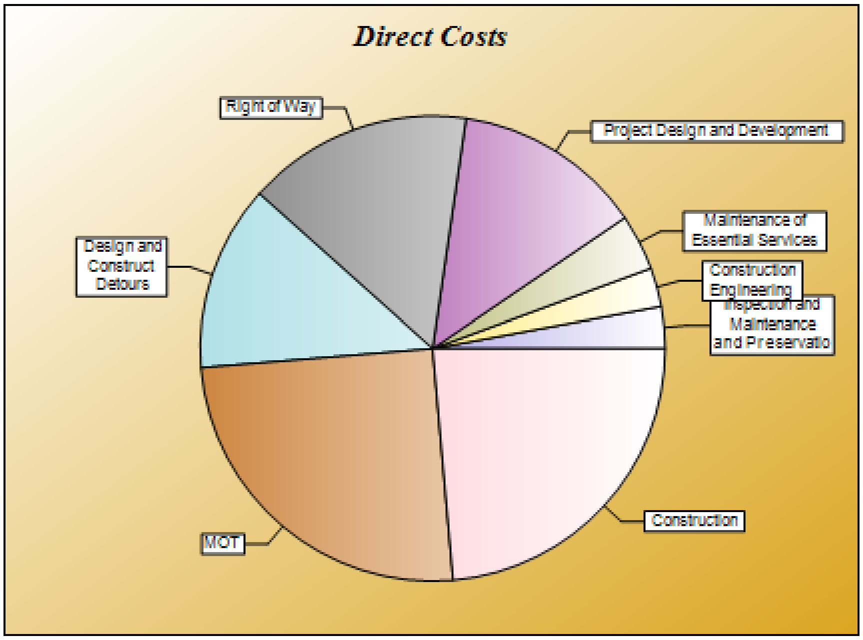


Figure 11: Sub-Criteria Weights for Direct Costs

Clear Creek, Gulick Lane Project in Oregon

Bridge info:

- Existing Bridge is on Clear Creek, Gulick Lane
- Existing Bridge length: 29ft steel girders on concrete vertical abutments
- The bridge is on a Rural Local road.
- ADT: 90
- Detour length: 1 mile
- The new bridge will be 80-100 ft in length

A Demonstration of Using ABC Decision Making Software for Clear Creek Project

This report summarizes the AHP analysis for the Clear Creek project. The required data for this analysis was provided by Oregon Department of Transportation. In this study, two construction alternatives are compared: Accelerated Bridge Construction method (ABC), and Conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the Conventional alternative is highly preferable over the ABC alternative for this project. The calculated utilities for the Conventional and ABC alternatives are 0.629 and 0.371, respectively.

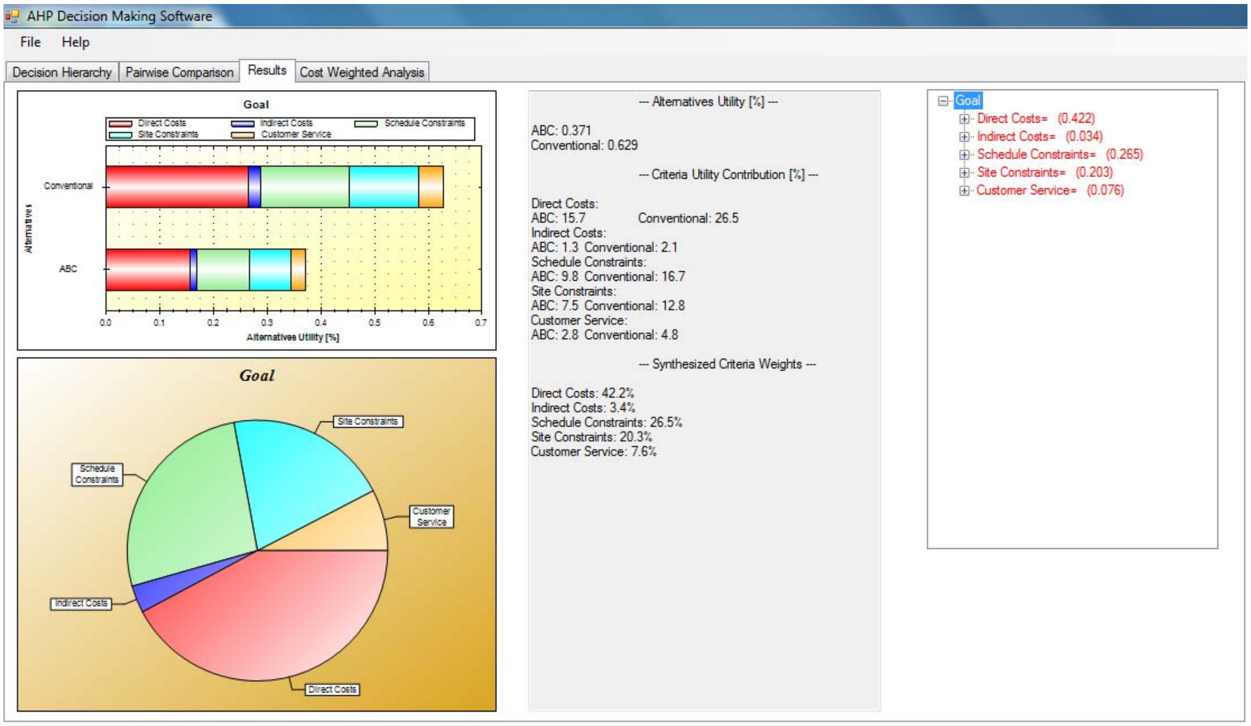


Figure 1: ABC Decision Making Software Output for the Clear Creek Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

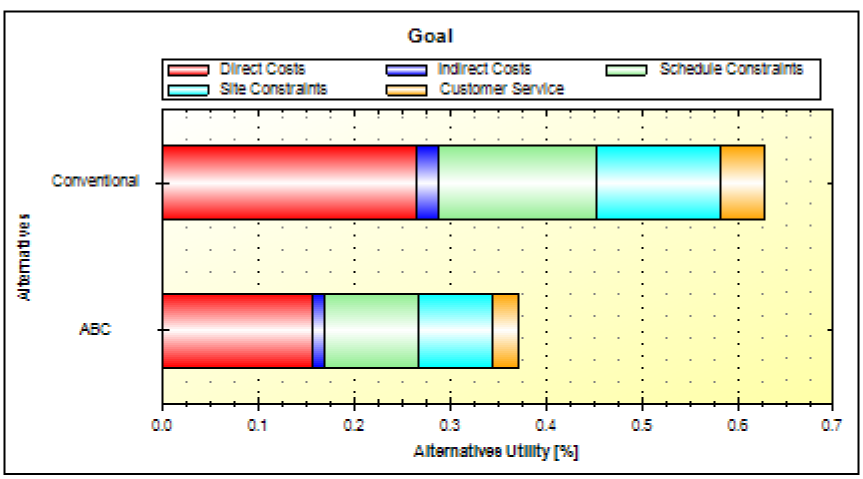


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Clear Creek project. The results indicate that “Direct Costs” and “Schedule Constraints” have the greatest impact on the decision to choose Conventional method as the suitable alternative.

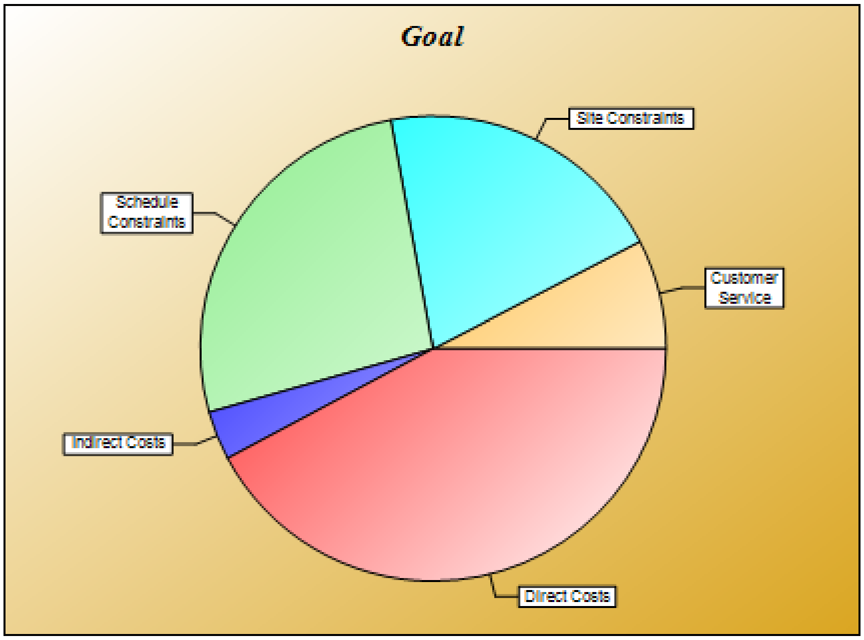


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (ABC or Conventional) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

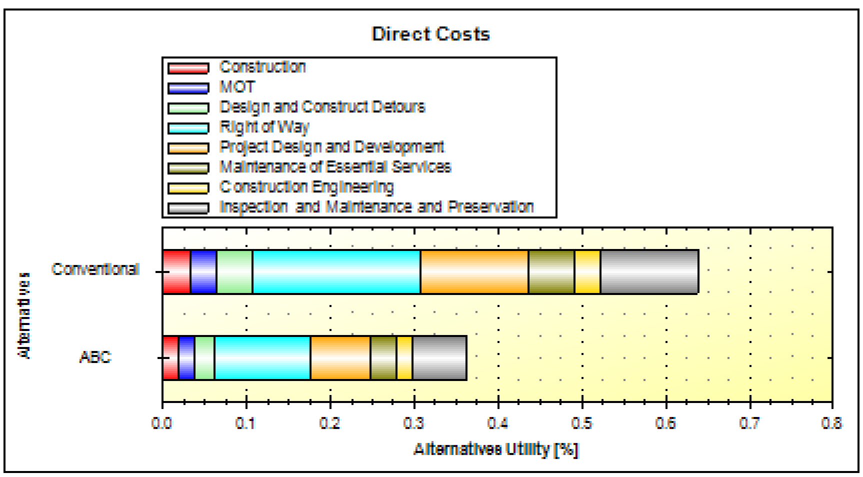


Figure 4: Ranks for Direct Costs

The analysis results related to the “Direct Costs” category are shown in Figures 4 and 5. In Figure 4, the amount of contribution of eight sub-criteria to the alternatives utility in this category is indicated. Figure 5 highlights that “Right of Way”, “Project Design and Development”, and “Inspection, Maintenance, and Preservation” are the three sub-criteria with the highest weight in the direct costs category.

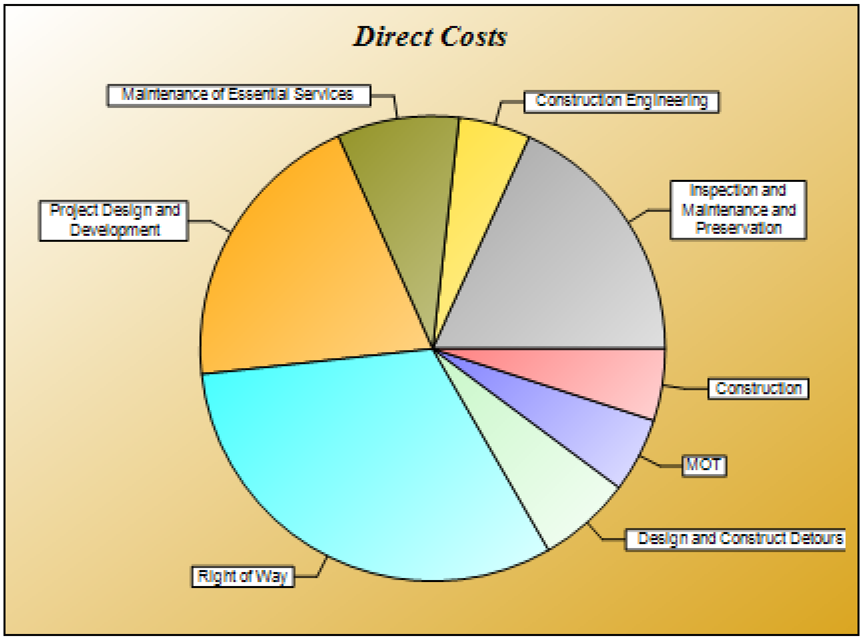


Figure 5: Sub-Criteria Weights for Direct Costs

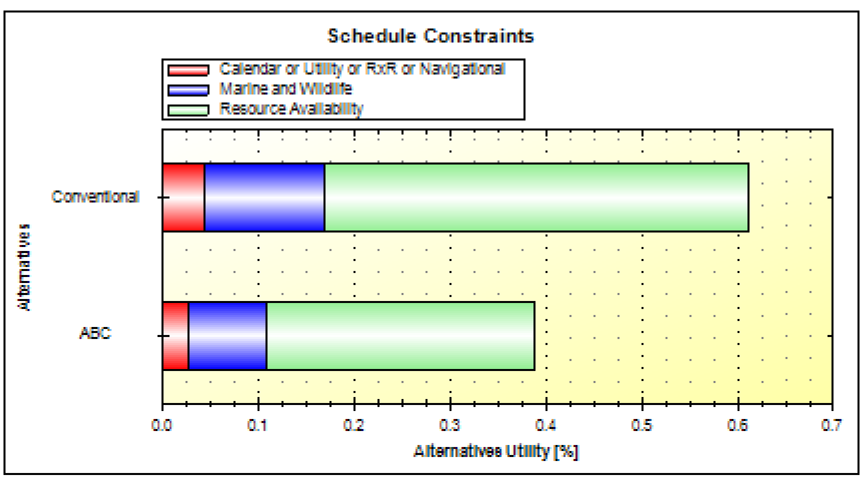


Figure 6: Ranks for Schedule Constraints

Figures 6 and 7 summarize the results for the “Schedule Constraints” category. Figure 6 indicates the alternatives utility with regard to this high-level criterion. Figure 7 highlights that “Resource Availability” has the greatest influence on the preference for the Conventional method over ABC in the schedule constraints category.

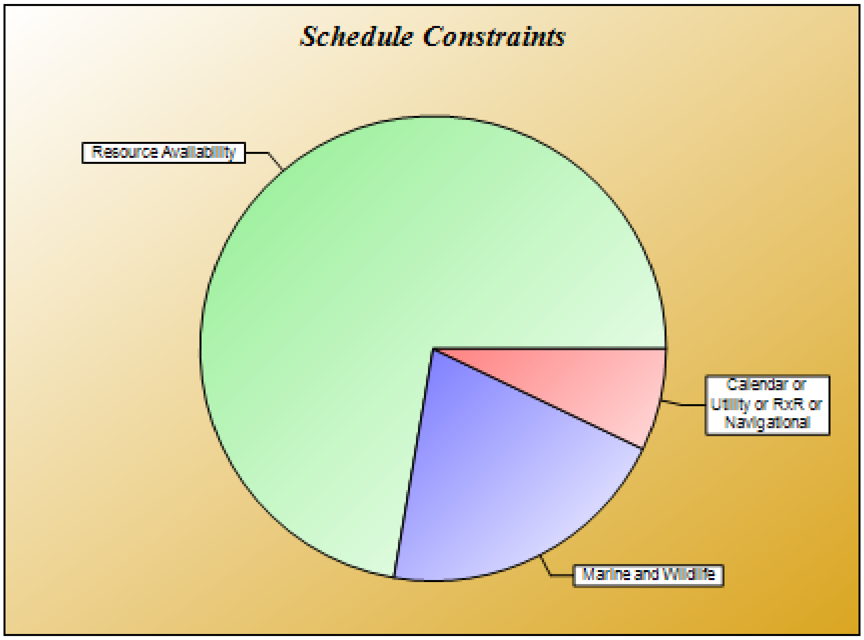


Figure 7: Criteria Weights for Schedule Constraints

Figures 8 and 9 summarize the results for the “Site Constraints” category. Figure 8 shows that the Conventional alternative is preferred when only Site Constraints criteria are considered. Figure 9 highlights that “Horizontal/Vertical Obstructions” criterion is the most important contributor to this preference.

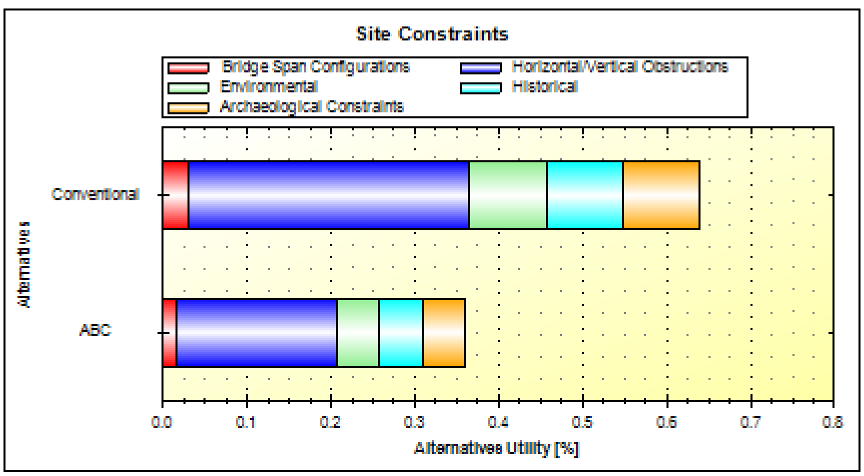


Figure 8: Ranks for Site Constraints

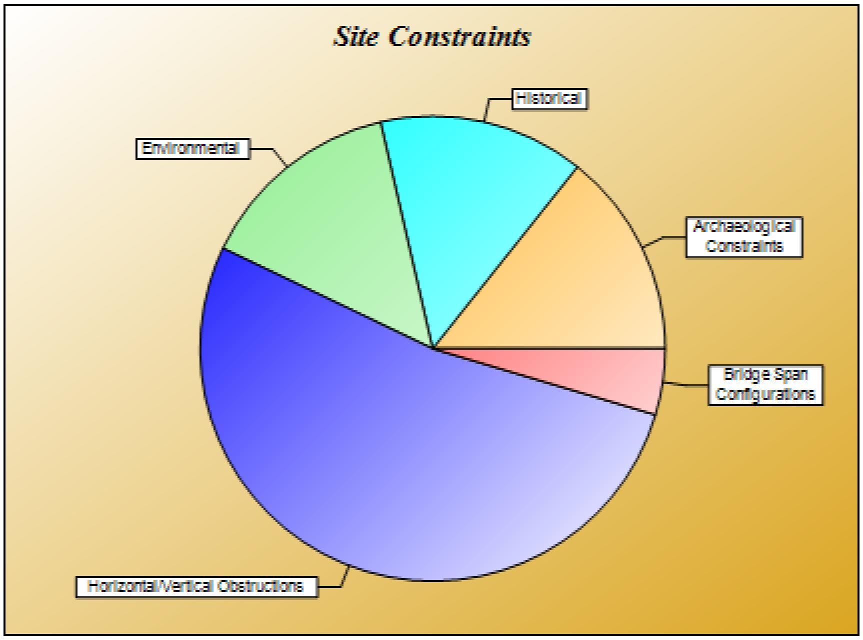


Figure 9: Sub-Criteria Weights for Site Constraints

Figures 10 and 11 summarize the results for the "Customer Service" category. Figure 10 shows that the Conventional alternative is highly preferred when only Customer Service criteria are considered. In Figure 11, it is highlighted that "Public Perception" has the greatest impact on this preference.

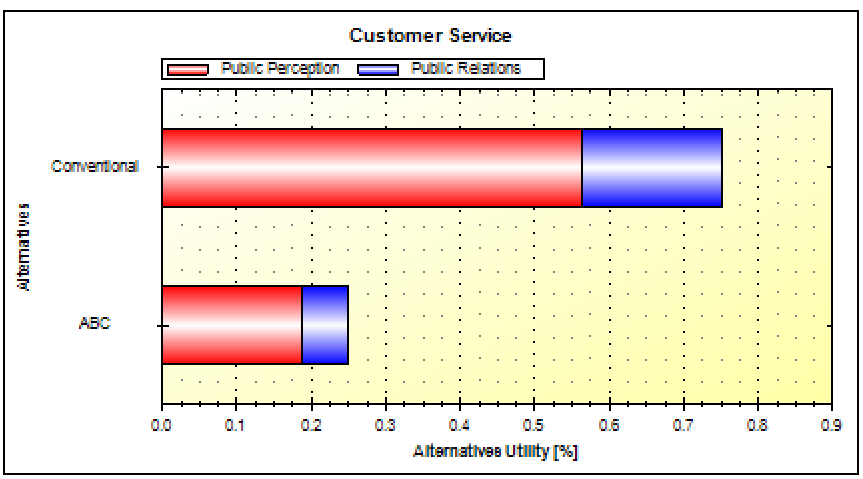


Figure 10: Ranks for Customer Service

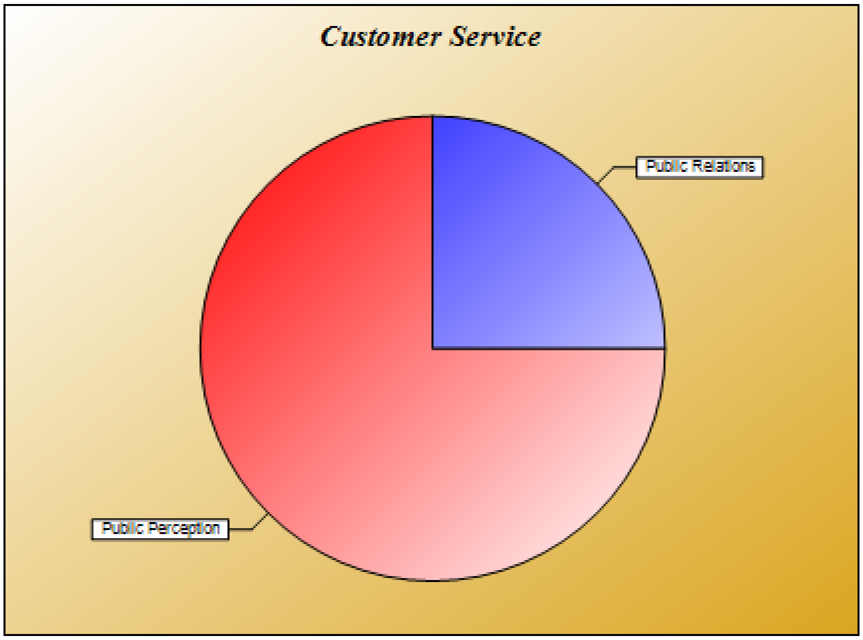


Figure 11: Sub-Criteria Weights for Customer Service

The last criterion with the lowest priority among the high-level criteria is “Indirect Costs”. The details of the analysis related to this criterion are shown in Figures 12 and 13. As it is indicated, Indirect Costs is the only category in which the ABC alternative is preferred over the Conventional method. In Figure 13, it is highlighted that “Construction Personnel Exposure” has the greatest impact on this preference.

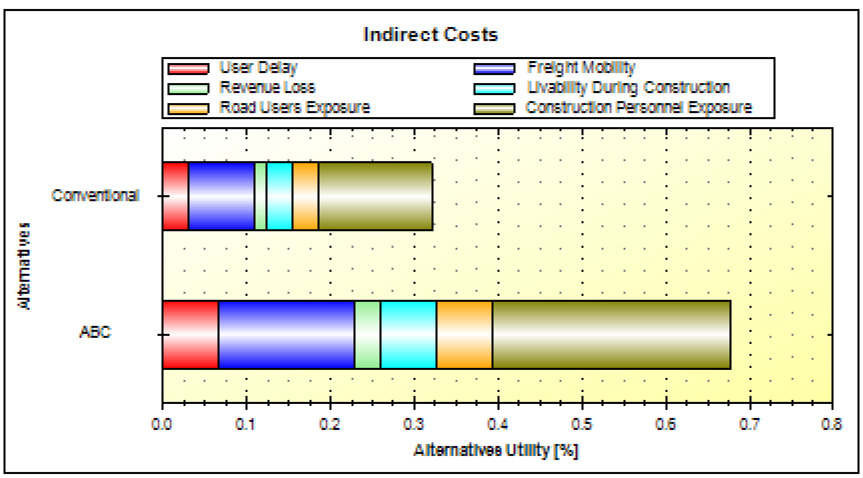


Figure 12: Ranks for Indirect Costs

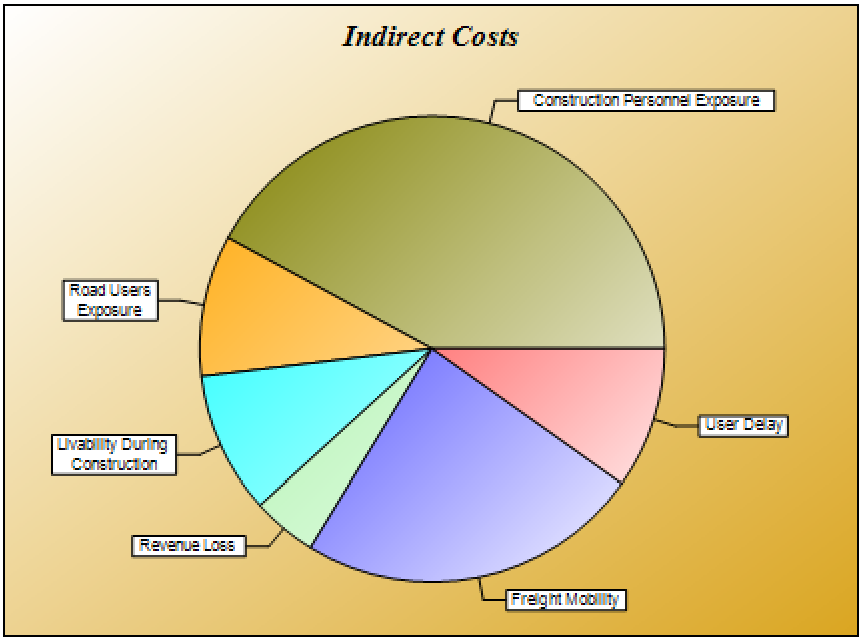


Figure 13: Sub-Criteria Weights for Indirect Costs

Copano Bay Bridge Project in Texas

The Copano Bay Bridge replaces the existing causeway on SH 35 at the mouth of Copano Bay. The bridge connects the cities of Rockport/Fulton and Lamar, on the Gulf Intracoastal Waterway. Copano Bay is home to oyster colonies and migratory birds, attracting birdwatchers year-round. Two peninsulas frame the bay opening, limiting ROW and dictating phased construction.

The bridge is 11,010 feet long, with a 129' wide and 75' tall navigation channel. The existing structure suffers severe corrosion from marine exposure, such that some piling members have failed and required extensive repair. As such, providing corrosion protection - in the form of high-performance concrete, stainless reinforcing steel, and cylinder pile foundations - was of high importance.

The superstructure is 100', 120', and 150' long prestressed concrete girders. A majority of the piers consist of cast-in-place caps on trestle piles, with the tallest piers around the navigation channel being CIP bent caps on CIP columns and waterline pile caps. Contractors may elect to propose precast bent caps as alternate construction, thus reducing the duration of construction activities over open water.

Figure 1 shows the Copano Bay channel span.

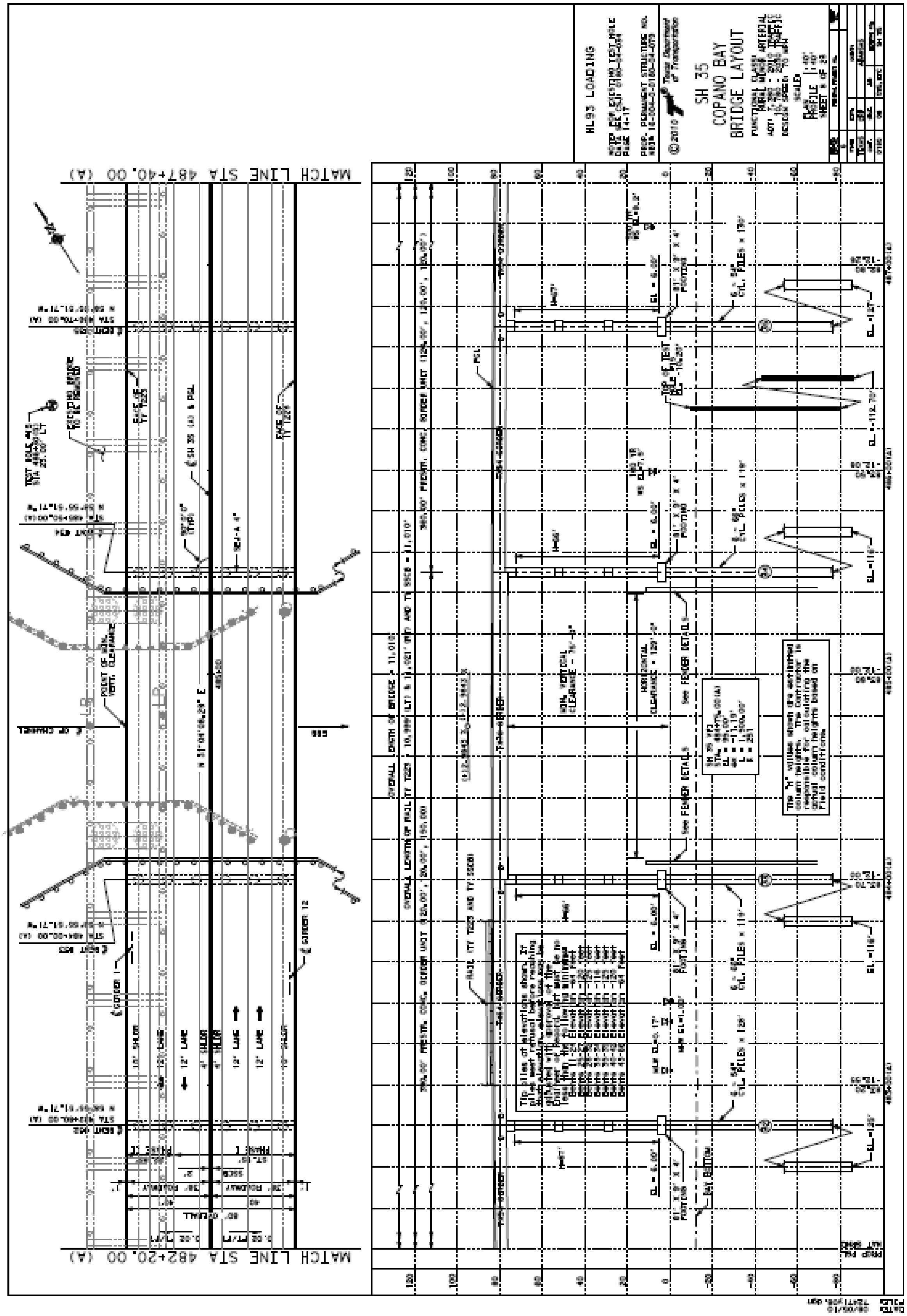


Figure 1: Copano Bay Channel

A Demonstration of Using ABC Decision Making Software for Copano Bay Bridge Project

This report summarizes the AHP analysis for the Copano Bay bridge project. The required data for this analysis was provided by Texas Department of Transportation. In this study, two construction alternatives are compared: Pre-Cast Caps (PCC), which is the accelerated method and Cast-In-Place (CIP), which is the conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 2 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the PCC alternative is highly preferable over the CIP alternative for the project. The calculated utilities for the PCC and CIP alternatives are 0.720 and 0.280, respectively.

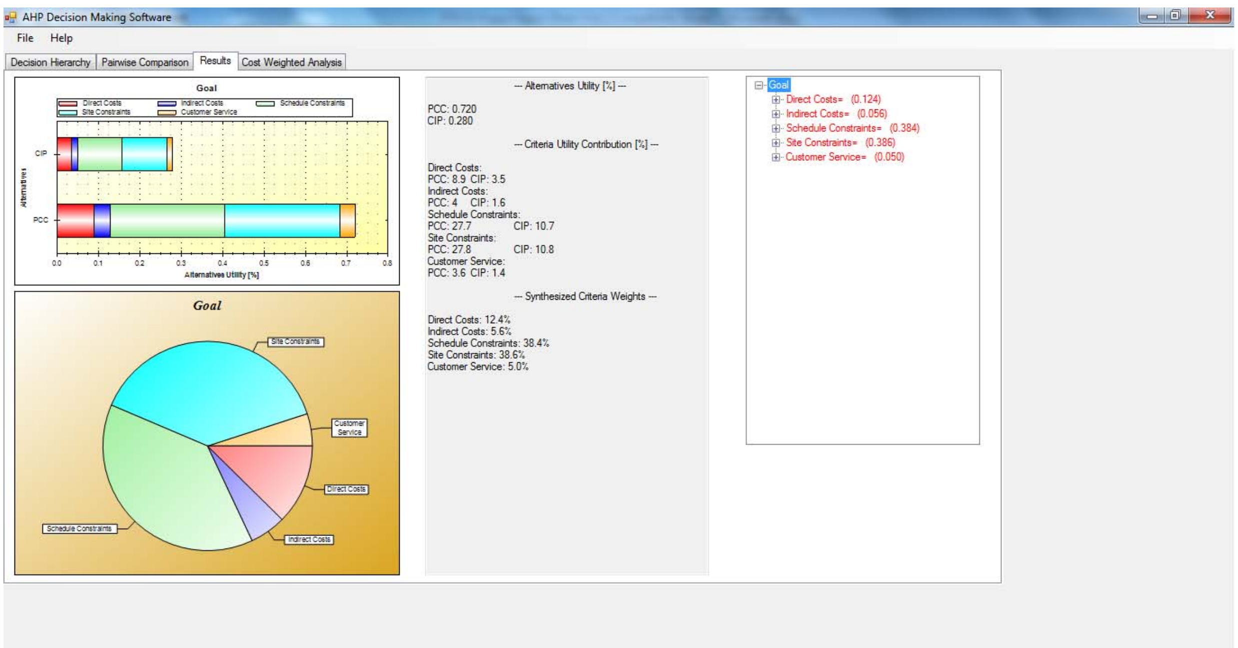


Figure 2: ABC Decision Making Software Output for the Copano Bay Bridge Project

Figure 3 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

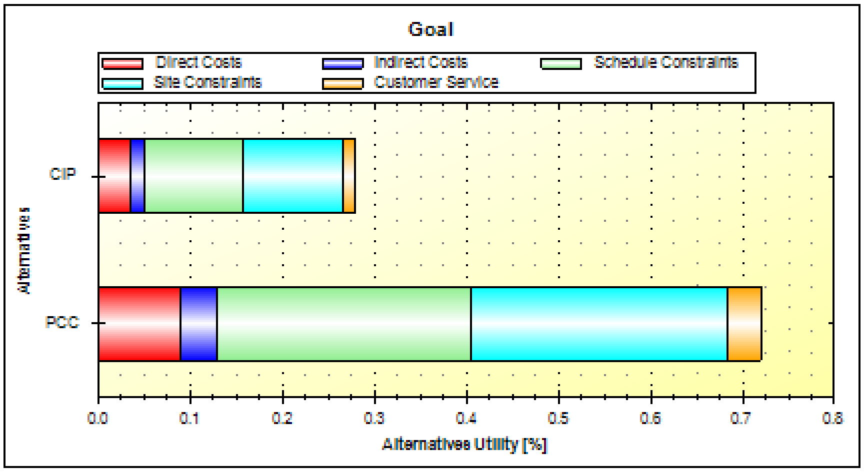


Figure 3: Criteria Utility Contribution

Figure 4 presents the high-level criteria weights for the Copano Bay Bridge project. The results indicate that “Site Constraints” and “Schedule Constraints” have the greatest impact on the decision to choose PCC as the suitable alternative.

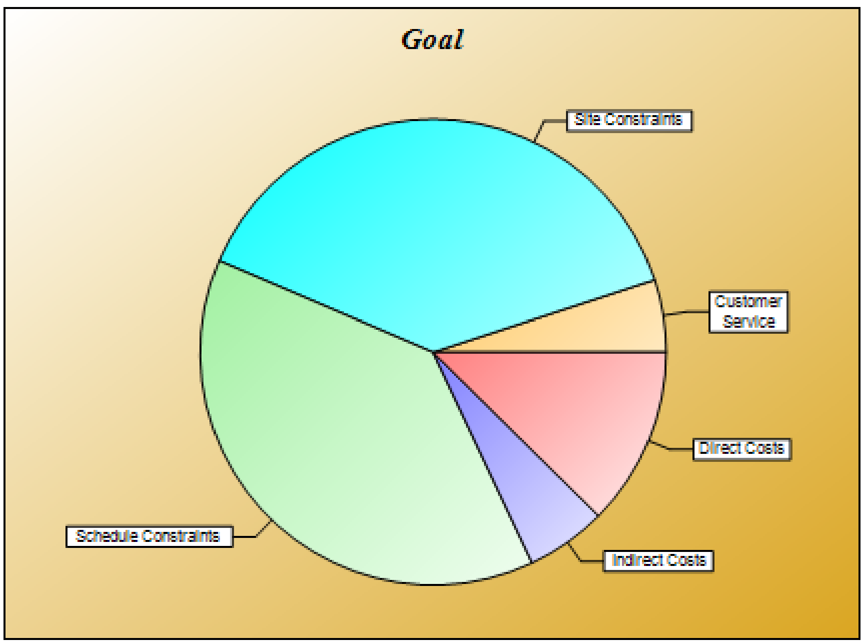


Figure 4: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (PCC or CIP) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 5 and 6 summarize the results for the "Site Constraints" category. Figure 5 indicates the alternatives utility with regard to this high-level criterion. Figure 6 highlights that "Horizontal/Vertical Obstructions" and "Environmental factors" have the greatest influence on the preference for PCC over CIP in the site constraints category.

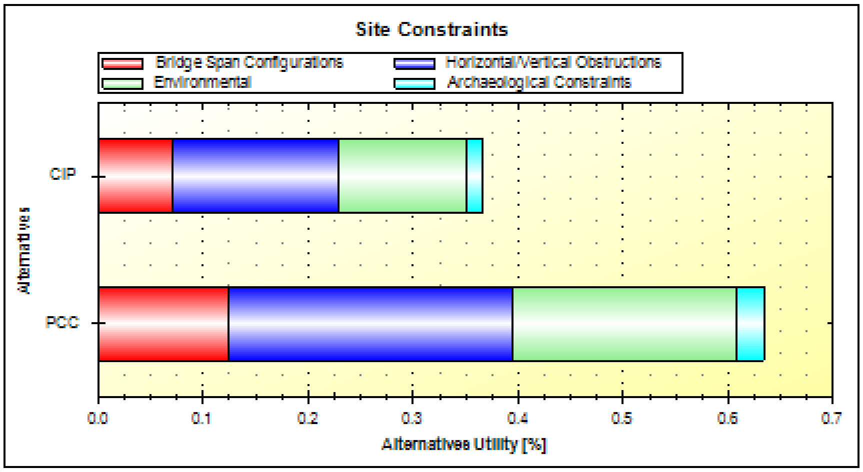


Figure 5: Ranks for Site Constraints

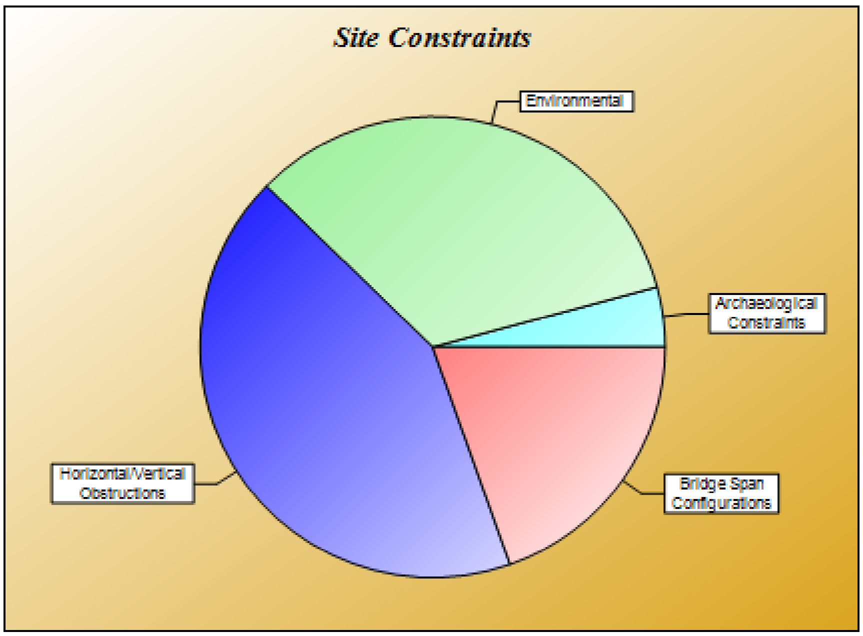


Figure 6: Sub-Criteria Weights for Site Constraints

Figures 7 and 8 summarize the results for the “Schedule Constraints” category. Figure 7 shows that the PCC alternative is highly preferred when only schedule constraints criteria are considered. Figure 8 highlights that “Marine and Wildlife” criterion is the most important contributor to this preference.

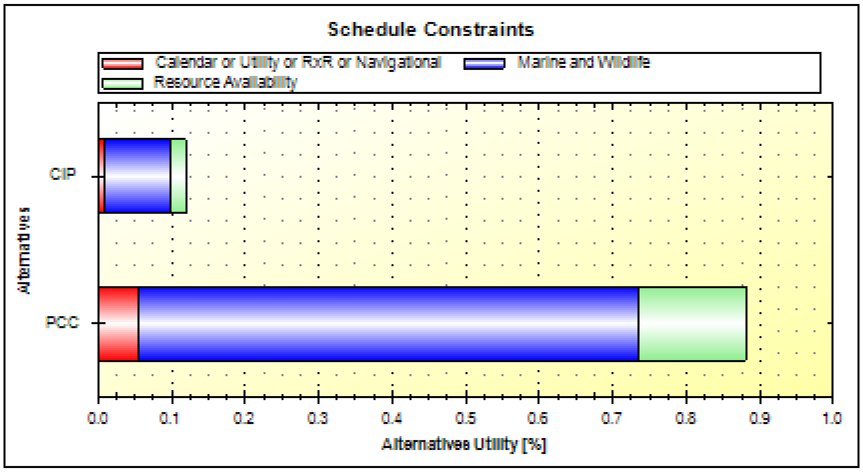


Figure 7: Ranks for Schedule Constraints

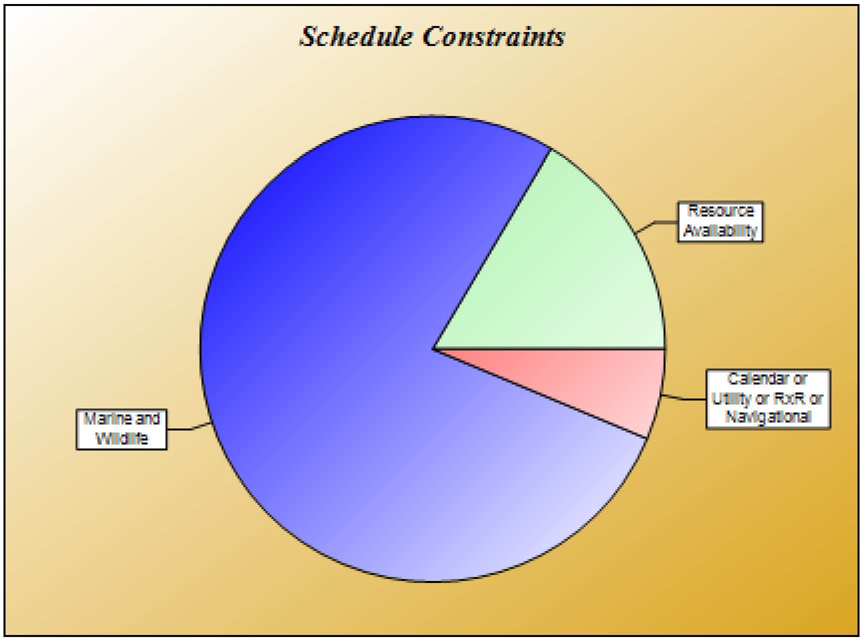


Figure 8: Criteria Weights for Schedule Constraints

The analysis results related to the "Direct Costs" category are shown in Figures 9 and 10. In Figure 9, the amount of contribution of eight sub-criteria to the alternatives utility in this category is indicated. Figure 10 highlights that "Right of Way" and "Inspection, Maintenance, and Preservation" are the two sub-criteria with the highest weight in the direct costs category.

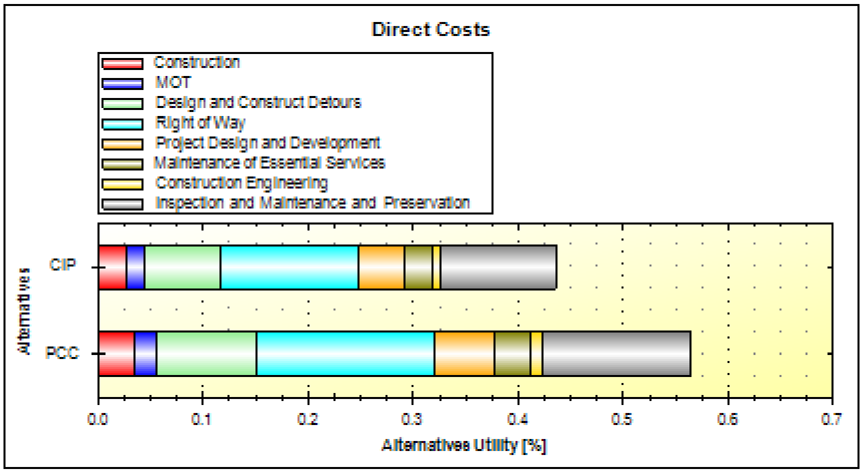


Figure 9: Ranks for Direct Costs

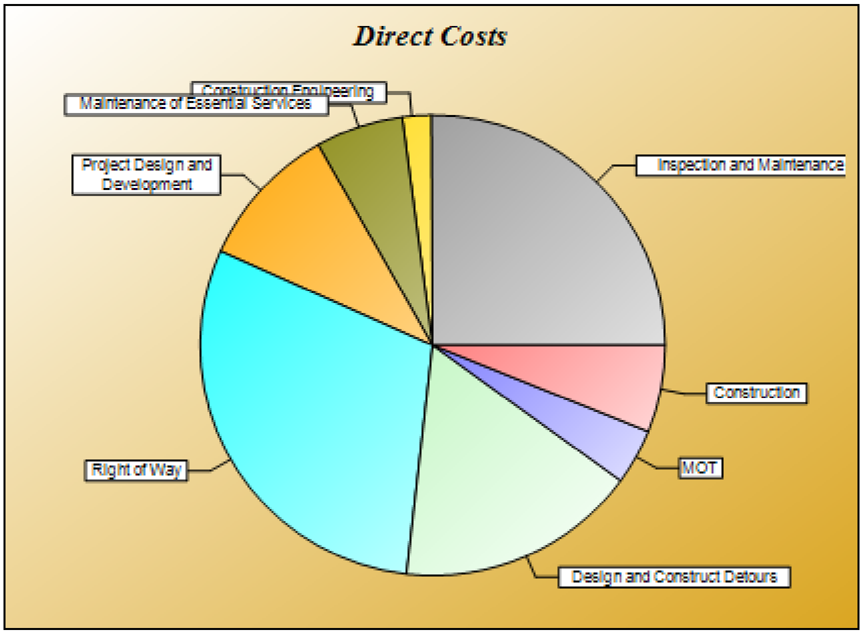


Figure 10: Sub-Criteria Weights for Direct Costs

Figures 11 and 12 summarize the results for the “Indirect Costs” category. Figure 11 shows that the PCC alternative is preferred when only Indirect Costs criteria are considered. Figure 12 highlights that the three criteria with the highest influence on this preference include “Construction Personnel Exposure”, “Revenue Loss”, and “Livability During Construction”.

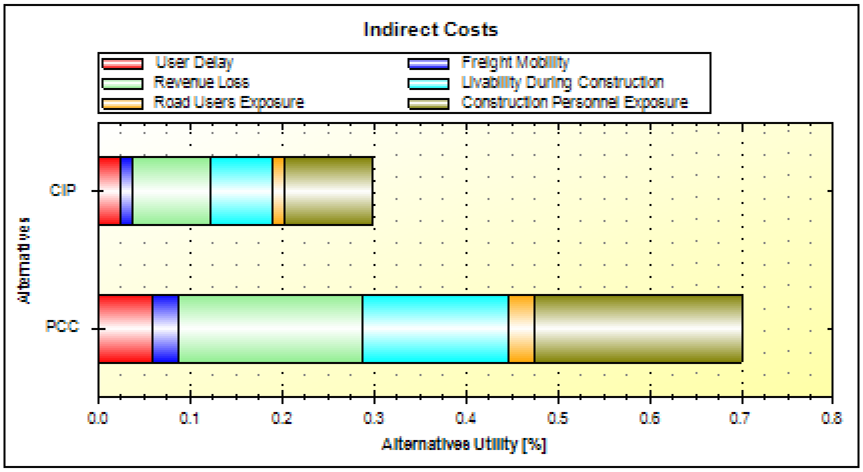


Figure 11: Ranks for Indirect Costs

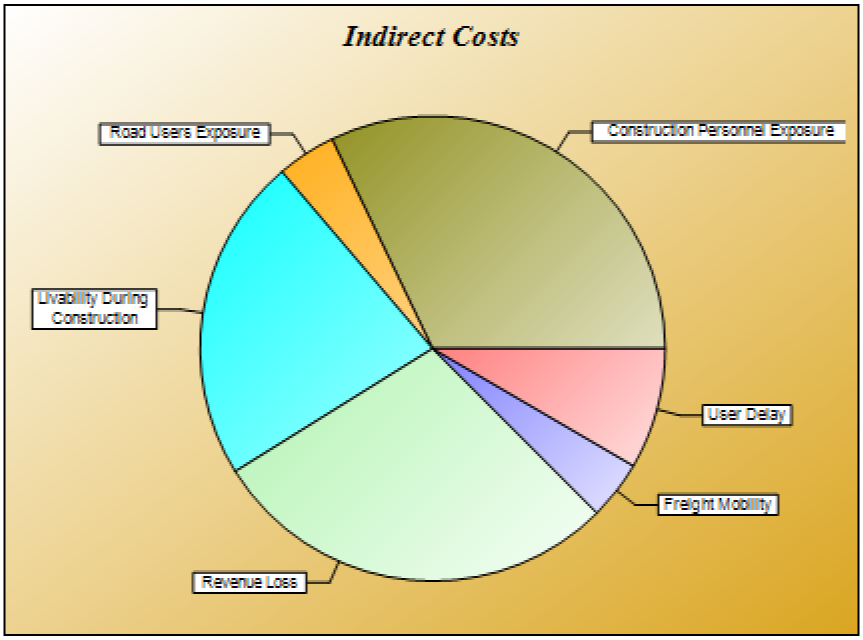


Figure 12: Sub-Criteria Weights for Indirect Costs

The last high-level criterion is “Customer Service”. The details of this analysis are shown in Figures 13 and 14. Figure 13 indicates that the PCC alternative is slightly preferred over CIP on the basis of customer service. In Figure 14, it is highlighted that “Public Relations” has the greatest impact on this preference.

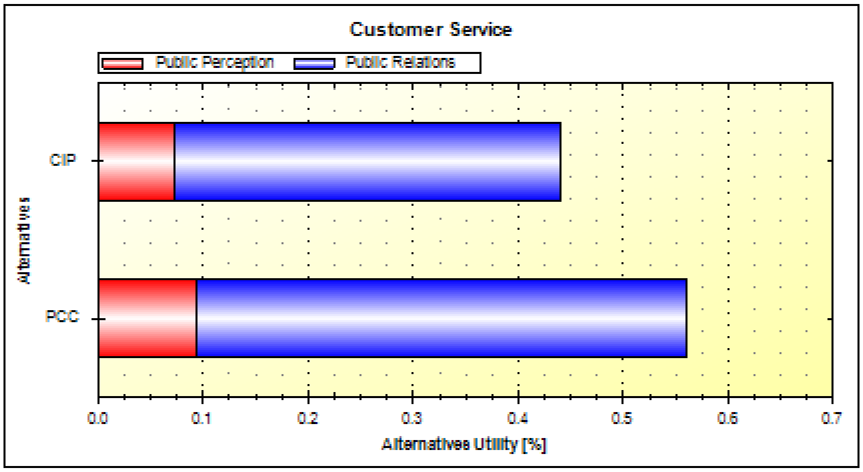


Figure 13: Ranks for Customer Service

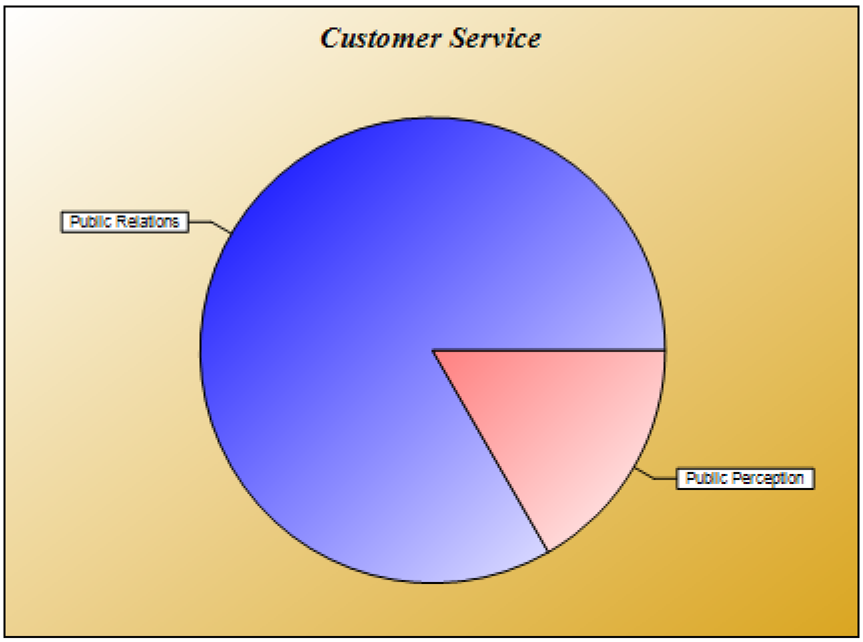


Figure 14: Sub-Criteria Weights for Customer Service

Redecking of Southbound IH-35W in Texas

Project description (location, purpose and scope):
Redecking of Southbound IH-35W over 36th Street and SL and SW Railroad
Fort Worth, Texas

The southbound bridge deck on the 232 ft long three-span continuous steel girder unit has deteriorated to a point where redecking is necessary. This steel girder unit is part of an overall 863 ft long bridge with the remaining spans of prestressed concrete beam construction. IH35W is an important north-south corridor in the Dallas-Fort WorthMetroplex, with a large volume of regional through traffic as well as commuter traffic carrying motorists to downtown Fort Worth. In addition to the redecking work, the bridge rails for the entire length of the bridge will be replaced to improve the vehicle retention of the barriers. No frontage roads exist at this location and traffic volume will not permit replacement in phases due to decreased traffic handling capacity. The southbound bridge will be closed either for nightly or weekend durations with traffic rerouted via IH 820. Because this detour route is relatively long at 14 miles and increase traffic volumes on IH 820, the number of closures will be kept at a minimum.

The primary innovative feature proposed for this work is the use of full depth-full width prefabricated bridge deck panels to minimize the duration of the nightly and/or weekend closures associated with redecking. Full depth-full width prefabricated deck panels greatly reduce the duration of deck construction since this eliminates the need for field placement of temporary or stay-in-place forms, reinforcing steel, and concrete placement, and the subsequent deck curing of 8 to 10 days. A conventional cast-in-place deck could well take three weeks of calendar time even with the usage of partial depth precast concrete subdeck panels.

A Demonstration of Using ABC Decision Making Software for Southbound IH-35W Project

This report summarizes the AHP analysis for the Southbound IH-35W Bridge Deck Project. The required data for this analysis was provided by Texas Department of Transportation. In this study, two construction alternatives are compared: Accelerated Bridge Construction method (ABC), and Conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the ABC alternative is preferable over the Conventional alternative for the project. The calculated utilities for the ABC and Conventional alternatives are 0.681 and 0.319, respectively.

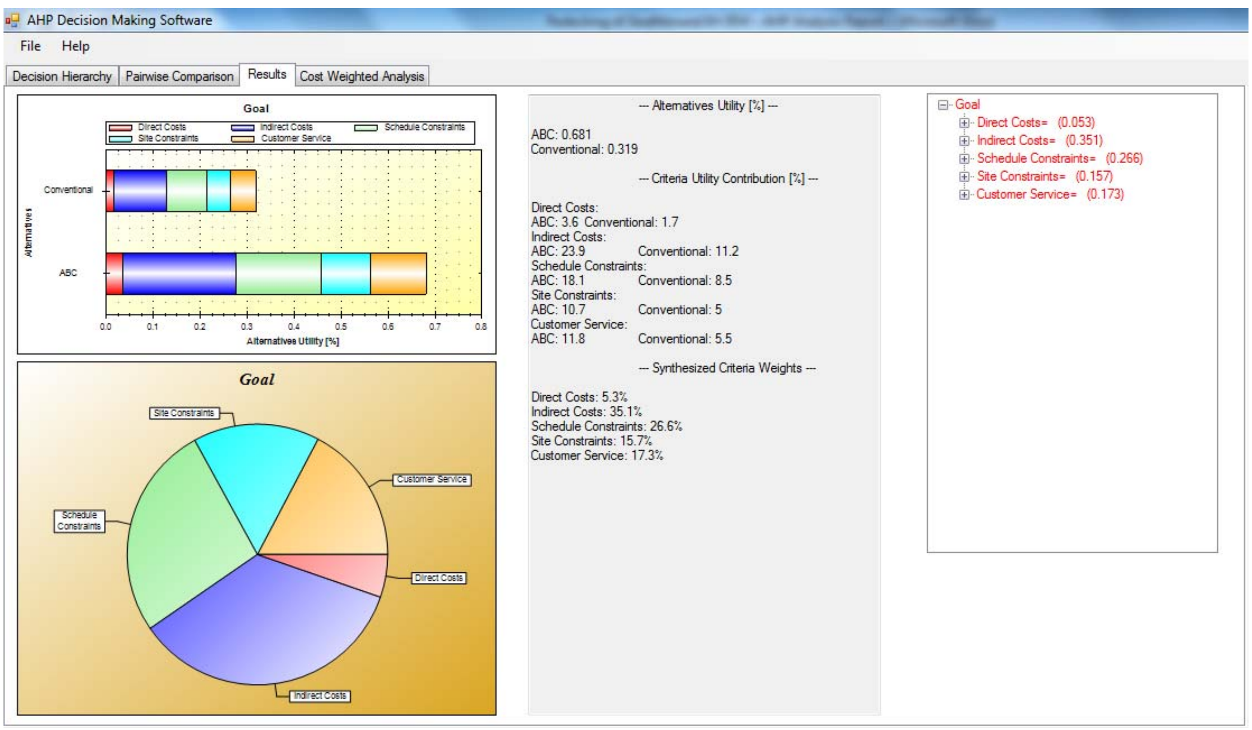


Figure 1: ABC Decision Making Software Output for the Southbound IH-35W Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

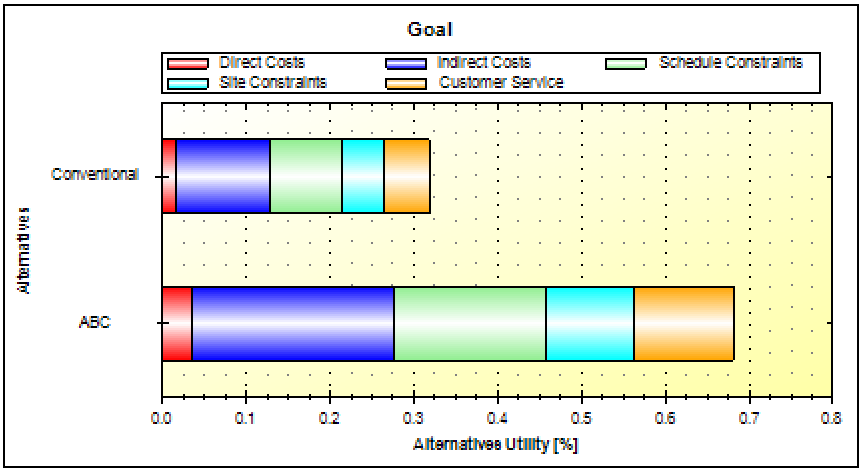


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Southbound IH-35W Project. The results indicate that "Indirect Costs" and "Schedule Constraints" have the greatest impact on the decision to choose ABC as the suitable alternative.

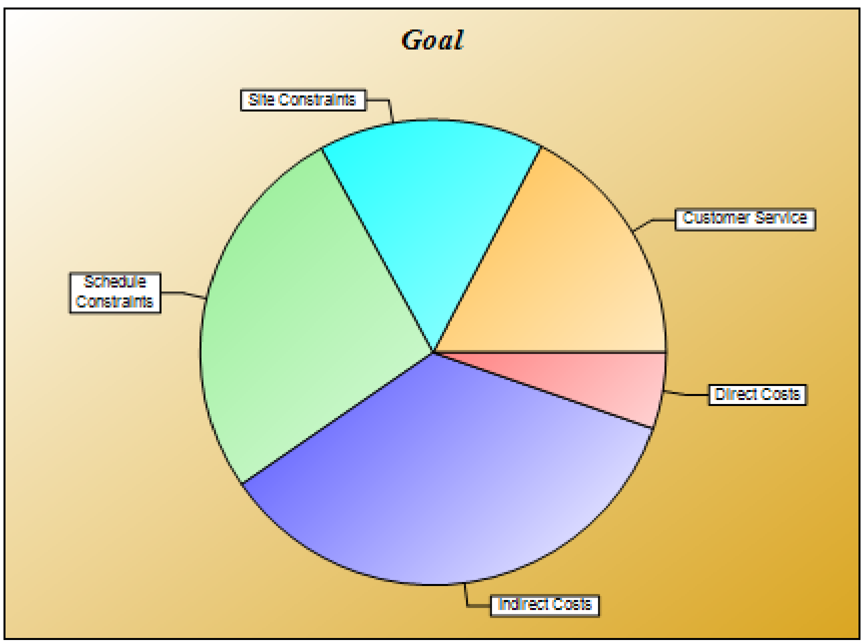


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (ABC or Conventional) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 4 and 5 summarize the results for the “Indirect Costs” category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 5 highlights that “Freight Mobility” and “Construction Personnel Exposure” have the greatest influence on the high preference for ABC over Conventional in the indirect costs category.

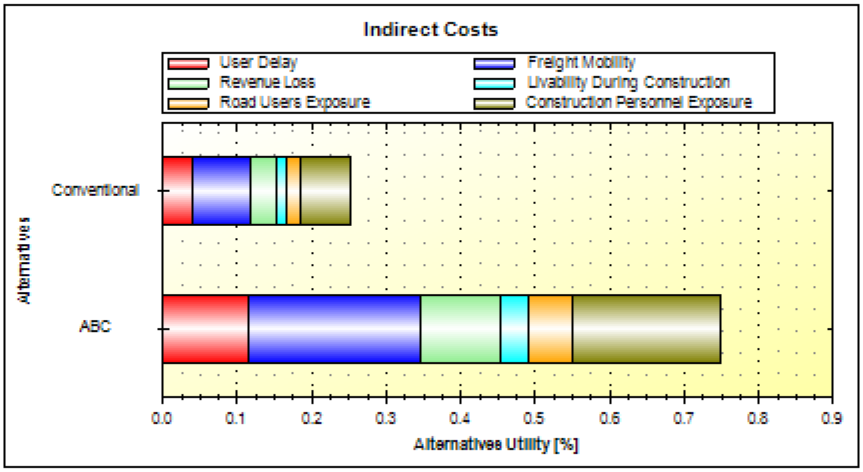


Figure 4: Ranks for Indirect Costs

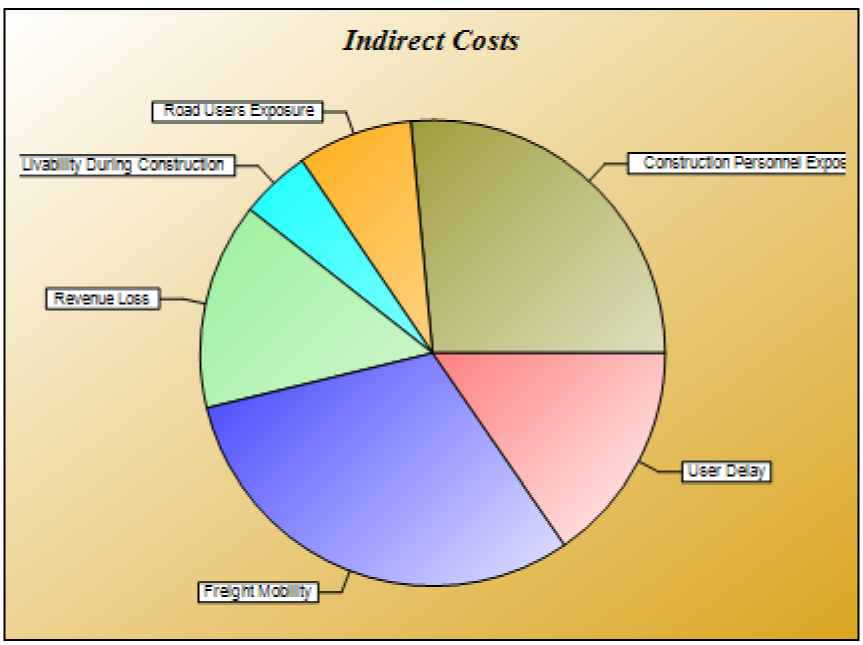


Figure 5: Sub-Criteria Weights for Indirect Costs

Figures 6 and 7 summarize the results for the "Schedule Constraints" category. Figure 6 shows that the ABC alternative is highly preferred when only Schedule Constraints criteria are considered. Figure 7 highlights that "Calendar or Utility or R×R or Navigational" criterion is the most important contributor to this preference.

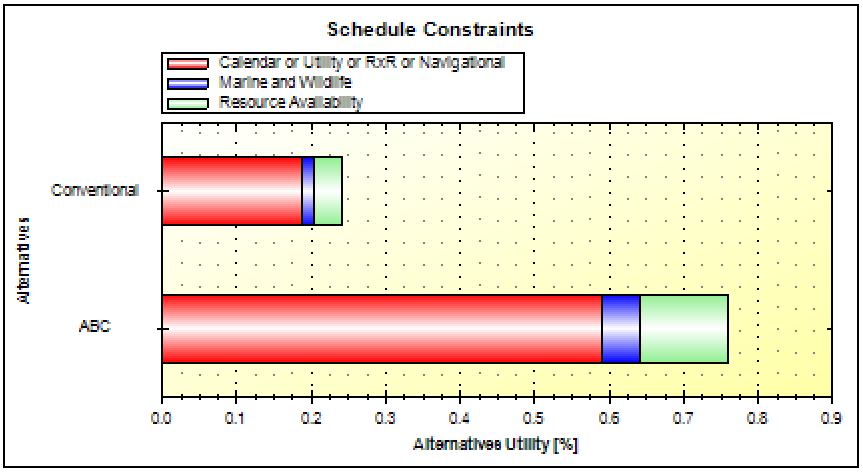


Figure 6: Ranks for Schedule Constraints

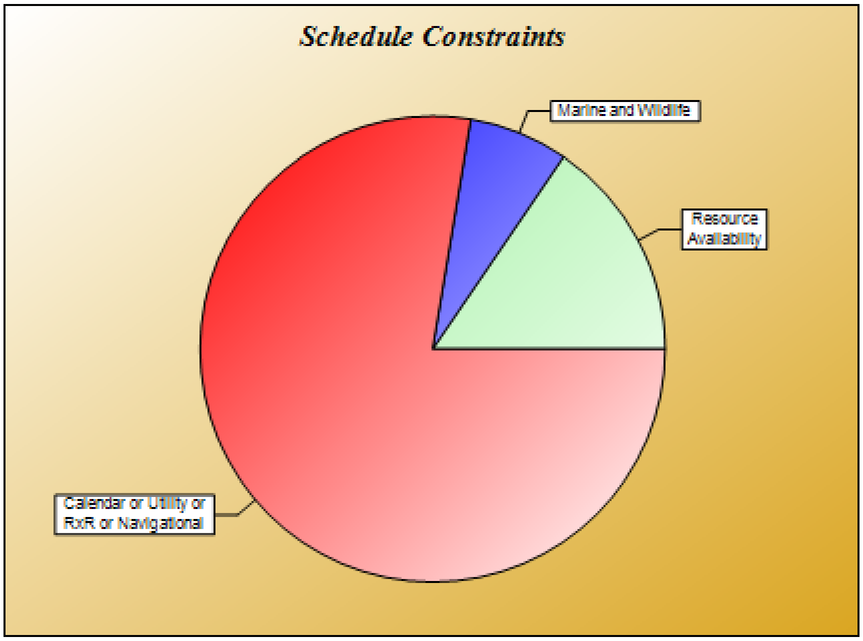


Figure 7: Criteria Weights for Schedule Constraints

The analysis results related to the “Customer Service” category are shown in Figures 8 and 9. Figure 8 shows that the ABC alternative has the same preference as the Conventional method when only Customer Service criteria are considered. In Figure 9, it is highlighted that “Public Perception” criterion has the greatest impact in this category.

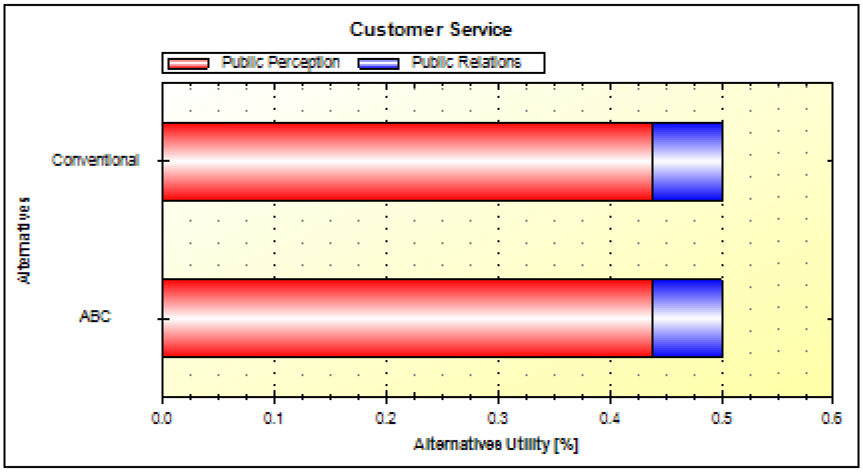


Figure 8: Ranks for Customer Service

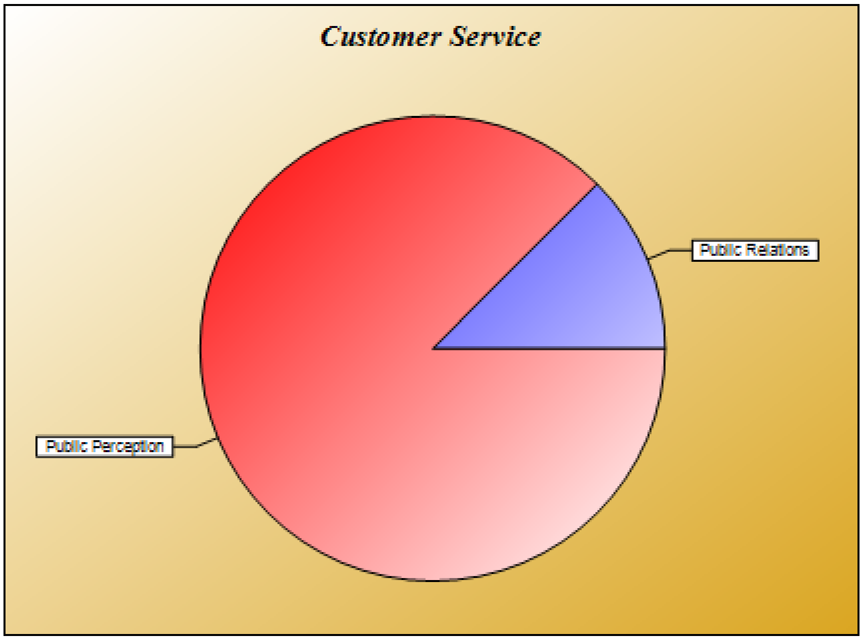


Figure 9: Sub-Criteria Weights for Customer Service

Figures 10 and 11 summarize the results for the "Site Constraints" category. Figure 10 shows that the ABC alternative is preferred when only Site Constraints criteria are considered. Figure 11 highlights that the most influential criterion in this category is "Bridge Span Configurations".

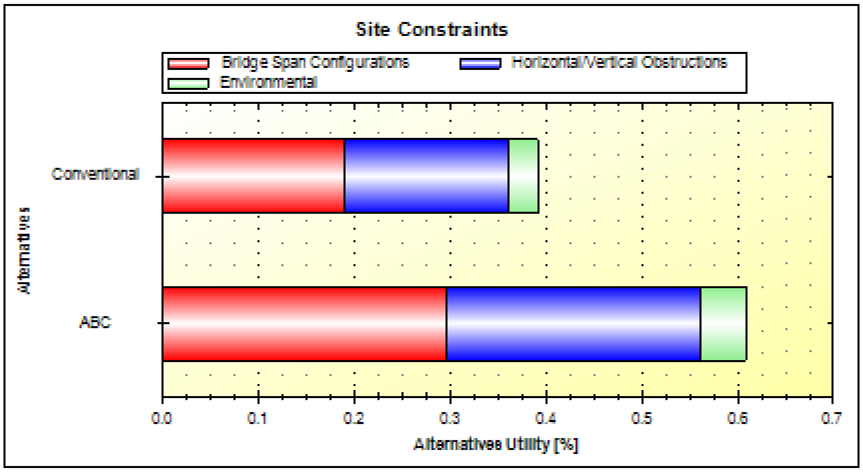


Figure 10: Ranks for Site Constraints

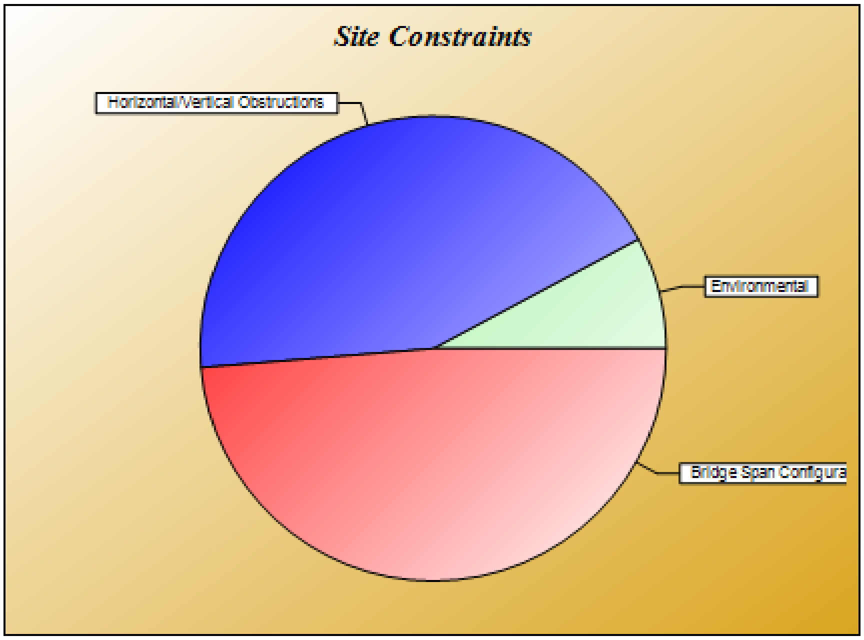


Figure 11: Sub-Criteria Weights for Site Constraints

The last criterion with the lowest priority among the high-level criteria is “Direct Costs”. In Figure 12, the amount of contribution of seven sub-criteria to the alternatives utility in this category is indicated. Figure 13 highlights that “Construction” and “Maintenance of Traffic” are the two sub-criteria with the highest weight in the direct costs category.

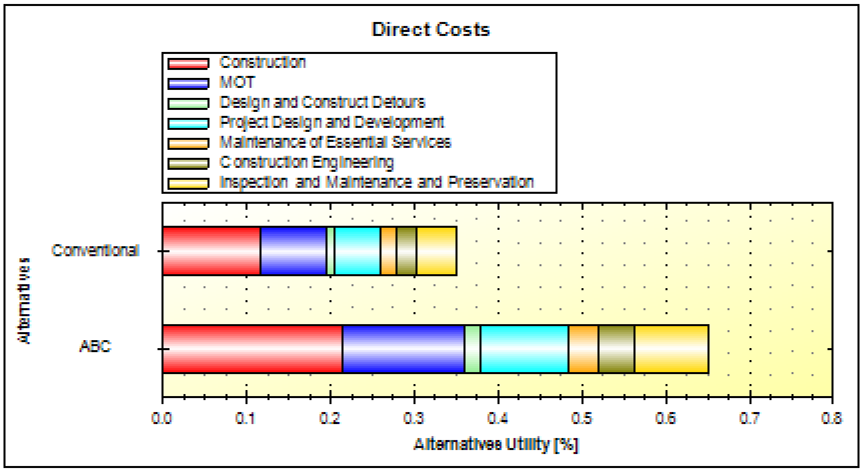


Figure 12: Ranks for Direct Costs

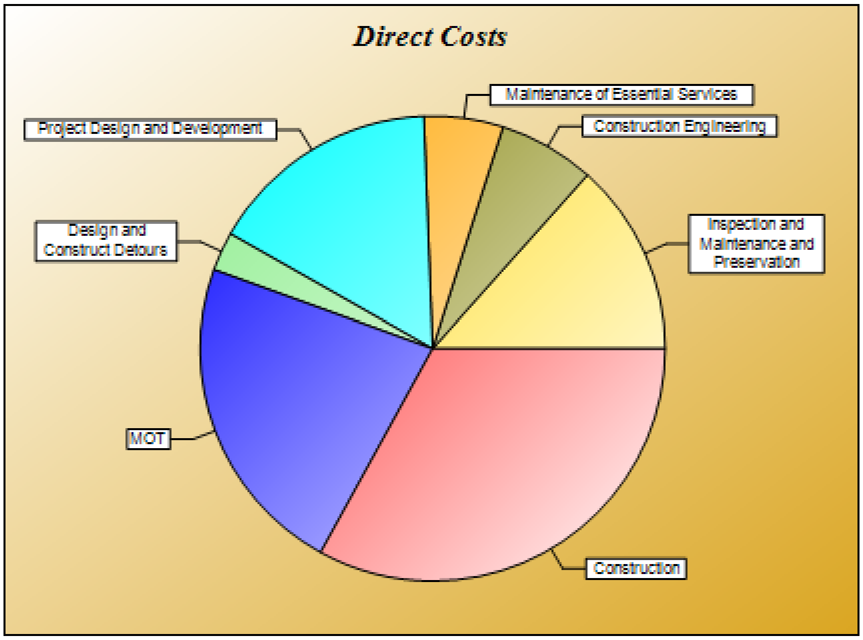


Figure 13: Sub-Criteria Weights for Direct Costs

Summit Park Bridge Project in Texas

Location: I-80 in Summit County at mile marker 141. It is considered a rural interstate at the location.
Length: 130 ft + 50 ft approach slabs
Width: 76 ft. 4 lanes

A Demonstration of Using ABC Decision Making Software for Summit Park Bridge Project

This report summarizes the AHP analysis for the Summit Park Bridge project. The required data for this analysis was provided by Utah Department of Transportation. In this study, two construction alternatives are compared: Transverse Slide and Phase Construction.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, Transverse Slide is a more suitable alternative for the project. The calculated utilities for the Transverse Slide and Phase Construction alternatives are 0.686 and 0.313, respectively.

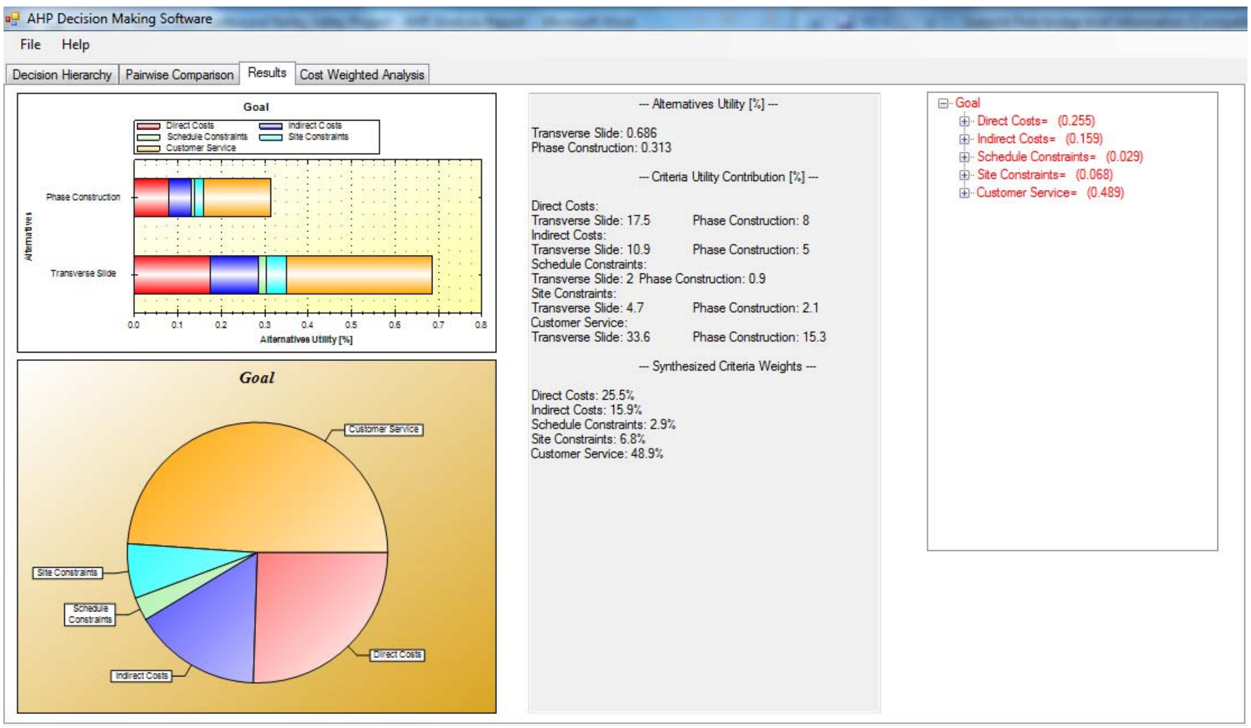


Figure 1: ABC Decision Making Software Output for the Summit Park Bridge Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

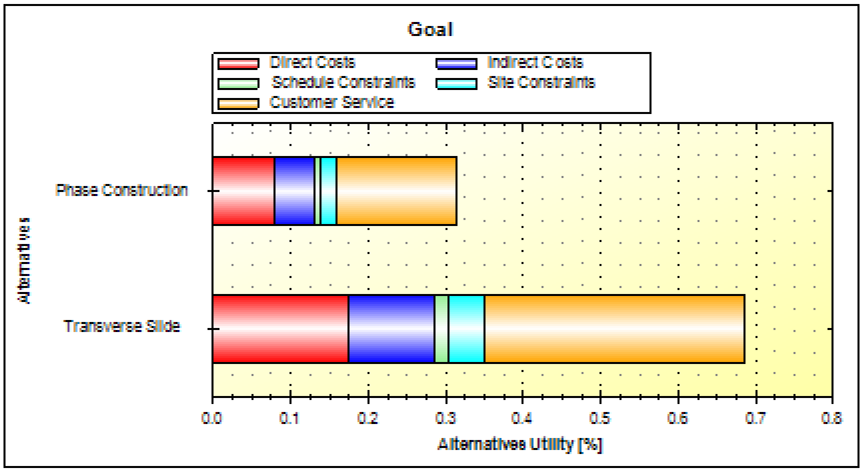


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Summit Park Bridge project. The results indicate that “Customer Service” has the greatest impact on the decision to choose Transverse Slide as the suitable alternative.

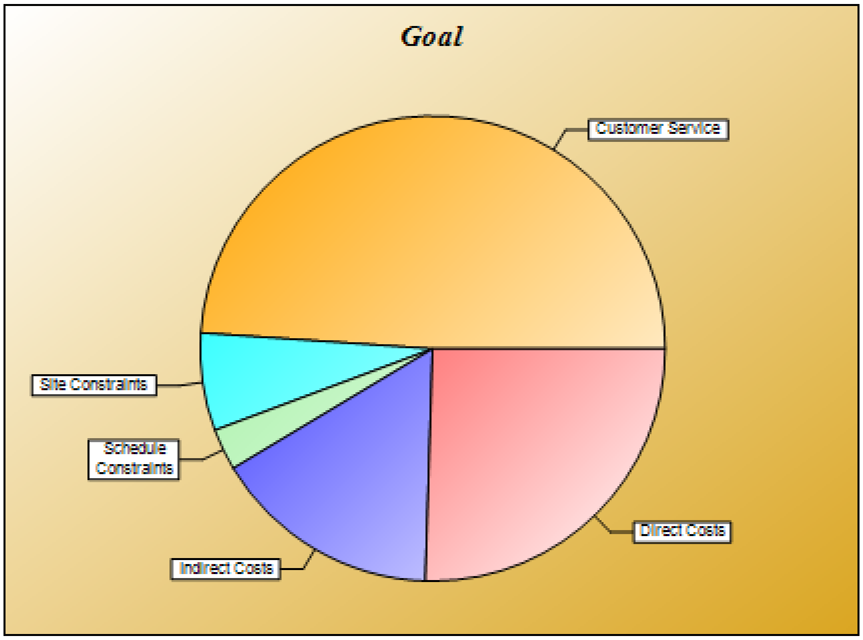


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the degree to which each alternative (Transverse Slide or Phase Construction) satisfies the goal with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 4 and 5 summarize the results for the "Customer Service" category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 5 highlights that "Public Perception" has more influence than "Public Relations" on the higher utility of "Transverse Slide" alternative in Customer Service category.

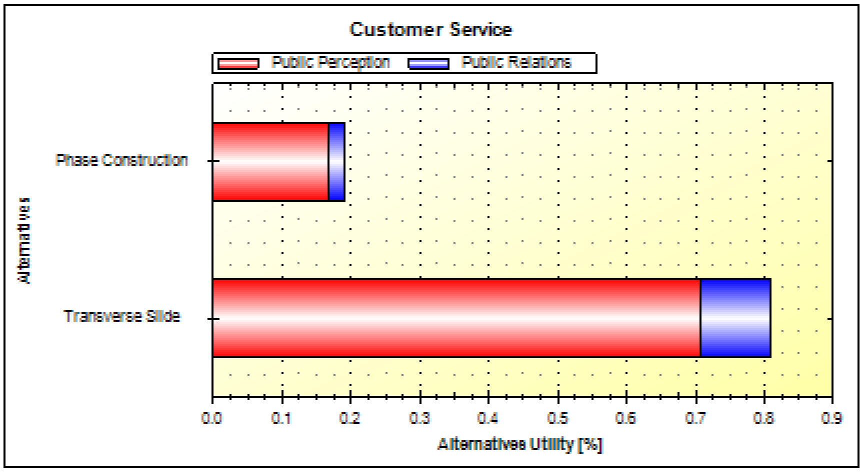


Figure 4: Ranks for Customer Service

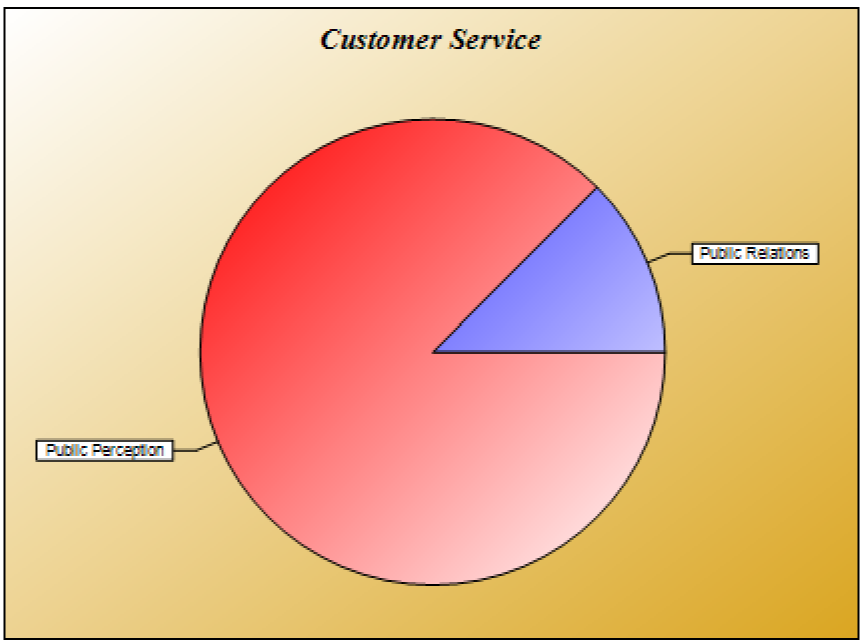


Figure 5: Sub-Criteria Weights for Customer Service

Figures 6 and 7 summarize the results for the "Direct Costs" category. Figure 6 shows that the Transverse Slide alternative utility is slightly higher than the Phase Construction alternative utility when only Direct Costs criteria are considered. Figure 7 highlights that "Construction" and "Inspection, Maintenance, and Preservation" are the most important contributors in this category.

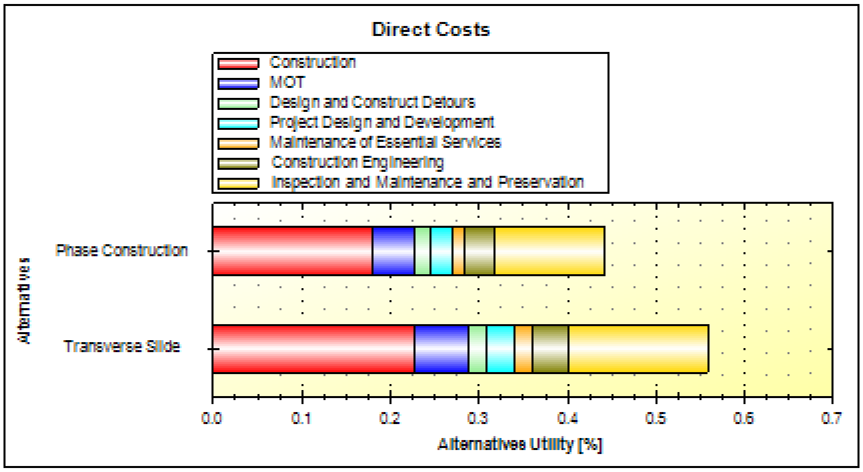


Figure 6: Ranks for Direct Costs

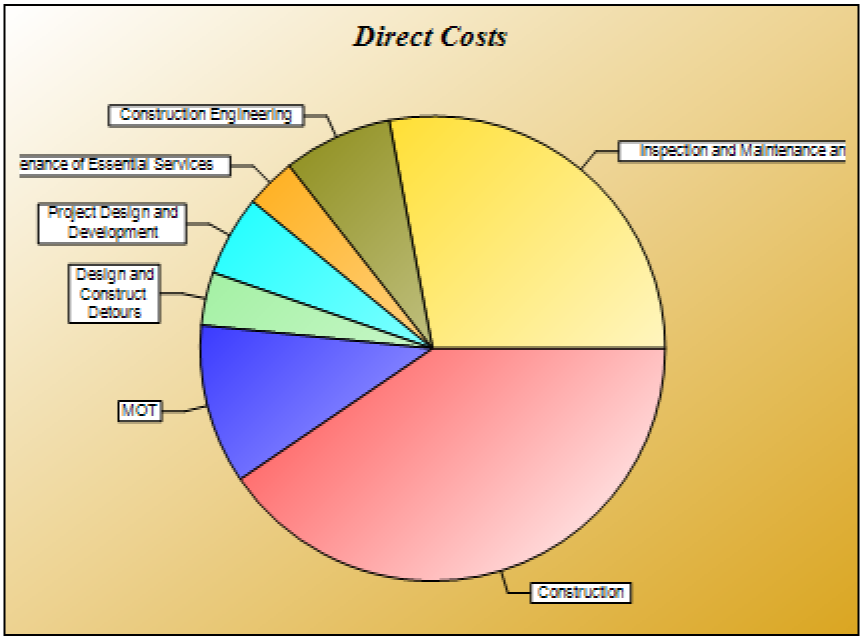


Figure 7: Criteria Weights for Direct Costs

The analysis results related to the “Indirect Costs” category are shown in Figures 8 and 9. In Figure 8, the amount of contribution of six sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that “User Delay” and “Freight Mobility” are the two sub-criteria with the highest weight in the Indirect Costs category.

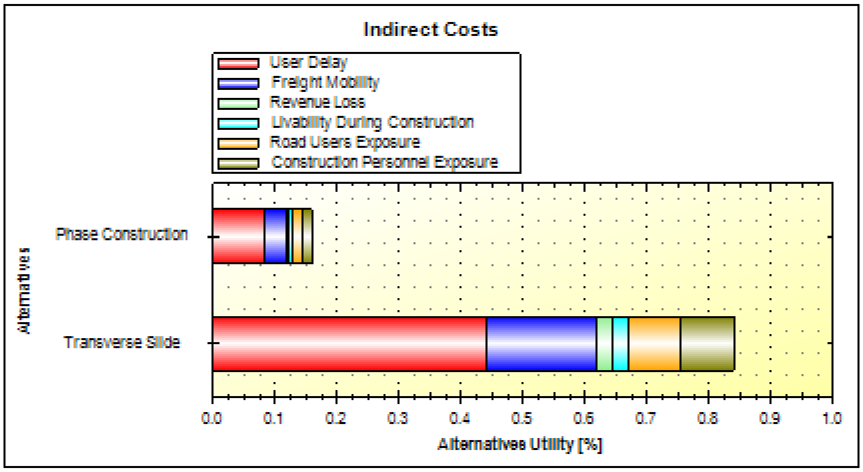


Figure 8: Ranks for Indirect Costs

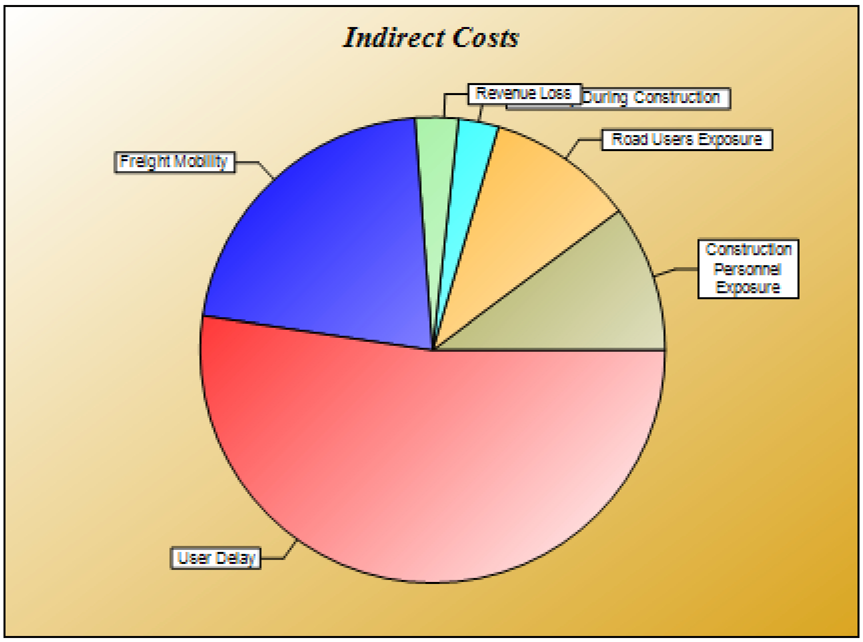


Figure 9: Sub-Criteria Weights for Indirect Costs

Figures 10 and 11 summarize the results for the "Site Constraints" category. Figure 10 shows that the degree to which Phase Construction alternative satisfies the goal is much higher than the other alternative when only Site Constraints criteria are considered. Figure 11 highlights that the most influential criterion in this category is "Horizontal/Vertical Obstructions".

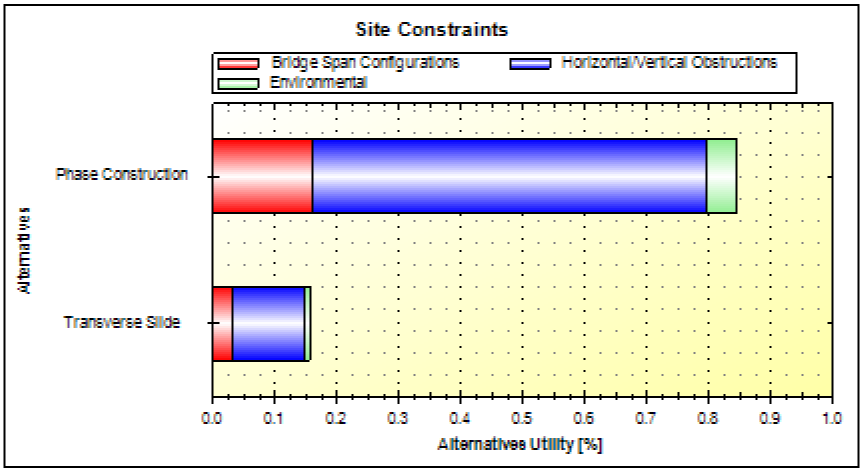


Figure 10: Ranks for Site Constraints

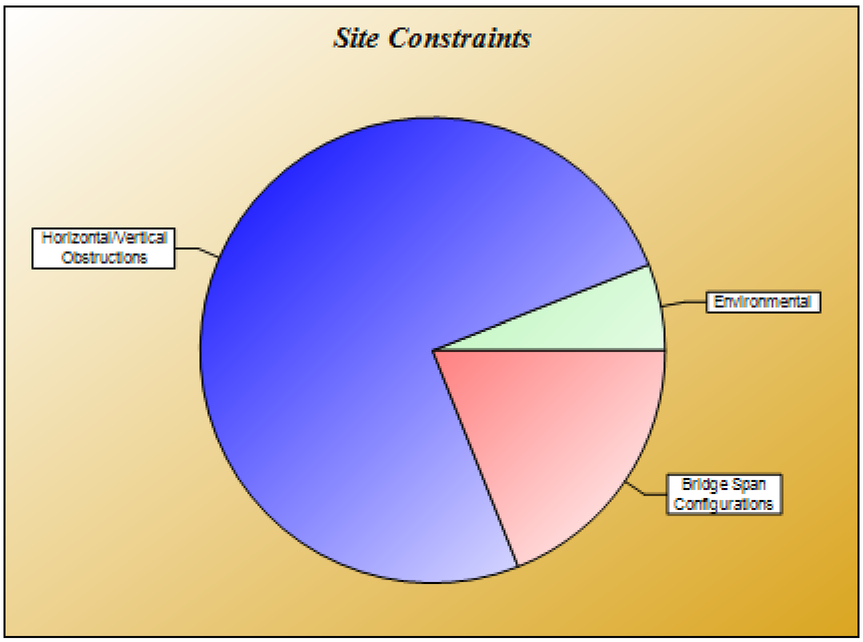


Figure 11: Sub-Criteria Weights for Site Constraints

The last high-level criterion is “Schedule Constraints”. The details of this analysis are shown in Figures 12 and 13. Figure 12 indicates that the Phase Construction alternative utility is higher than the Transverse Slide utility on the basis of Schedule Constraints. In Figure 13, it is highlighted that “Calendar or Utility or R×R or Navigational” has the greatest impact in this category.

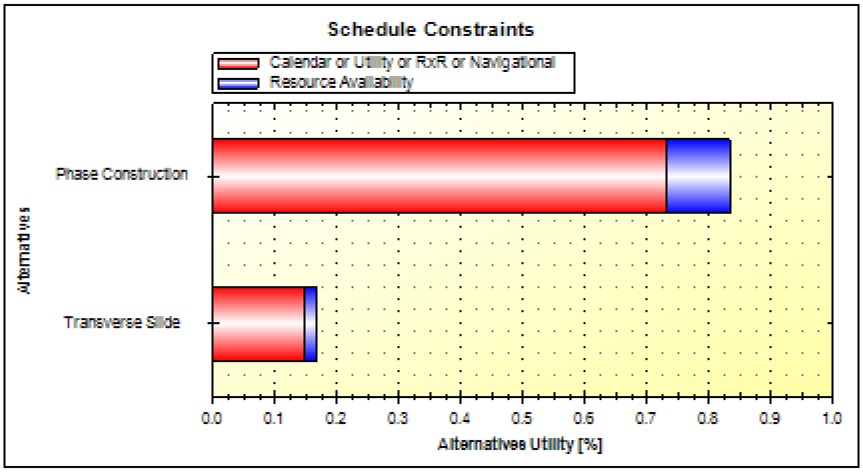


Figure 12: Ranks for Schedule Constraints

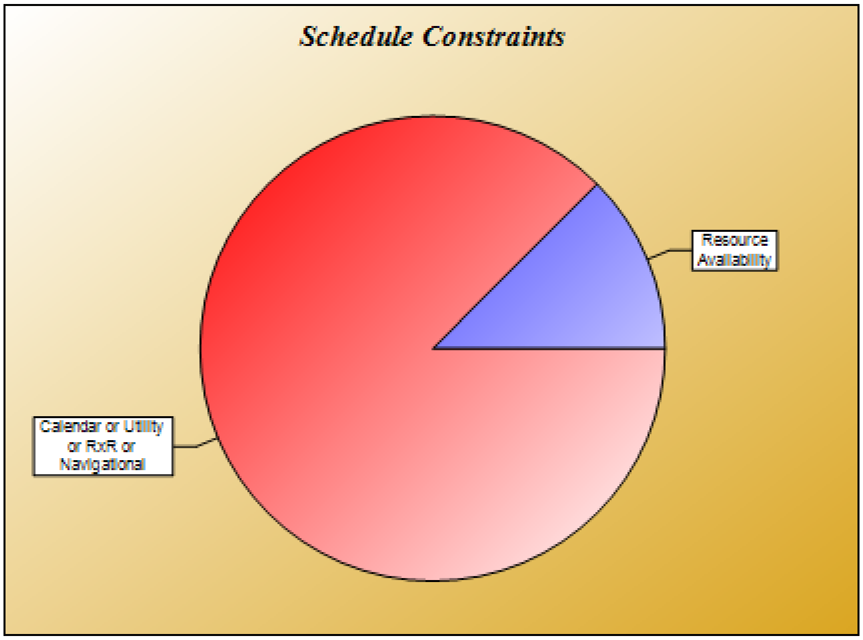


Figure 13: Sub-Criteria Weights for Schedule Constraints

Grand Mound to Maytown - Stage Two – Interchange Replacement Project in Washington

The bridge is located on Interstate 5 about 15 miles south of Olympia Washington. This bridge will replace an existing structure on a slightly new alignment to create a diamond interchange that will increase mobility and safety. The bridge will carry State Route 12 over Interstate 5. The bridge is 90 feet wide and 176 feet in length carrying two vehicular lanes and a bike lane in each direction along with a back to back left turn pocket and sidewalks on both sides.

The superstructure consists of two 88 foot spans constructed with W35DG deck bulb tee prestressed concrete girders. There is a 5” reinforced concrete deck, and the two spans are made continuous for live load.

The substructure has cast in place abutments and the center pier has cast in place footings with precast columns and x-beams. The girders are fitted with precast intermediate diaphragms and small end diaphragms that act as formwork for the center pier diaphragm. The x-beam has special precast end panels that allow the center pier diaphragm to be cast in place with very little formwork.

A Demonstration of Using ABC Decision Making Software for Grand Mound Project

This report summarizes the AHP analysis for the Grand Mound project. The required data for this analysis was provided by Washington State Department of Transportation. In this study, two construction alternatives are compared: Pre-Cast Columns (PCC), which is the accelerated method and Cast-In-Place (CIP), which is the conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the PCC alternative is slightly preferable over the CIP alternative for the project. The calculated utilities for the PCC and CIP alternatives are 0.529 and 0.470, respectively.

Figure 1: ABC Decision Making Software Output for the Grand Mound Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

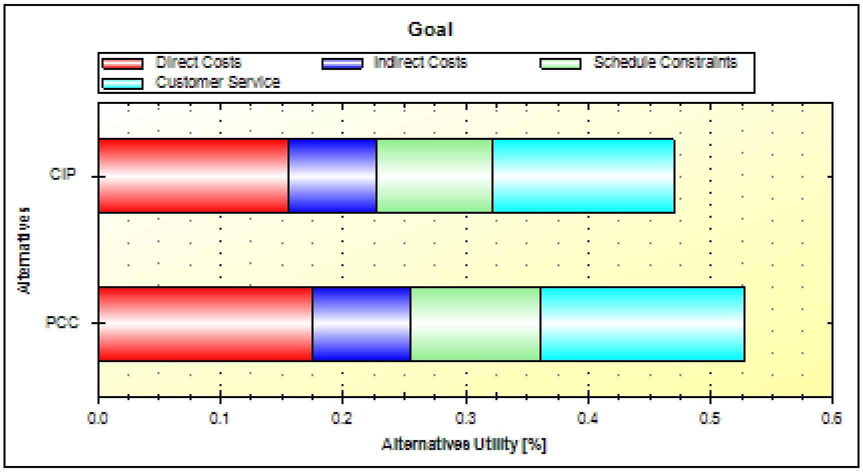


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Grand Mound project. The results indicate that "Direct Costs" and "Customer Service" have the greatest impact on the decision to choose PCC as the suitable alternative.

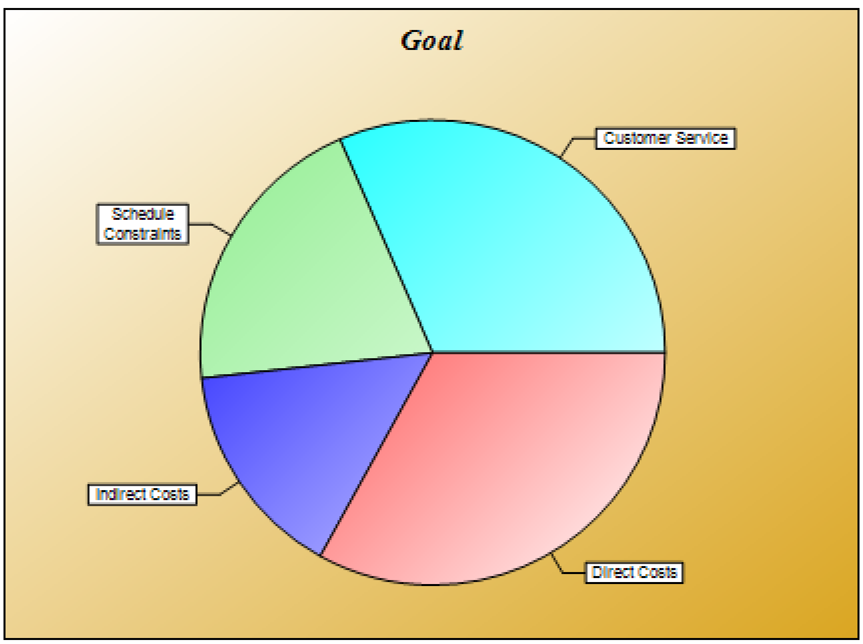


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (PCC or CIP) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 4 and 5 summarize the results for the “Direct Costs” category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 5 highlights that “Maintenance of Traffic” and “Construction” have the greatest influence on the preference for CIP over PCC in the direct costs category.

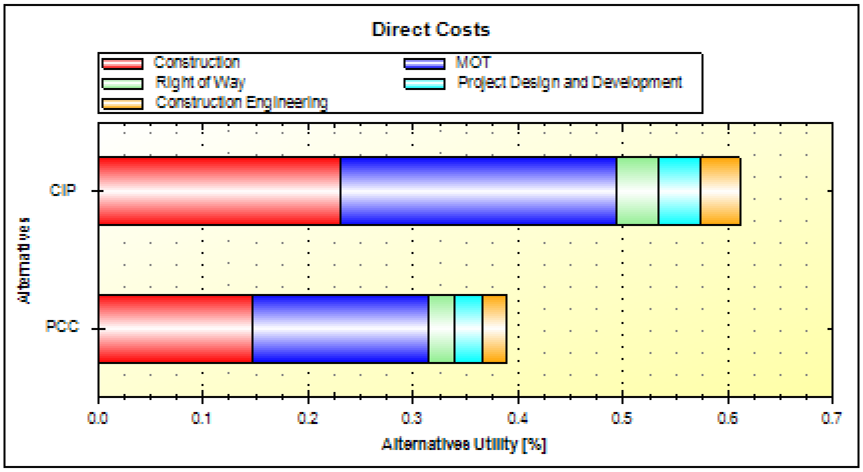


Figure 4: Ranks for Direct Costs

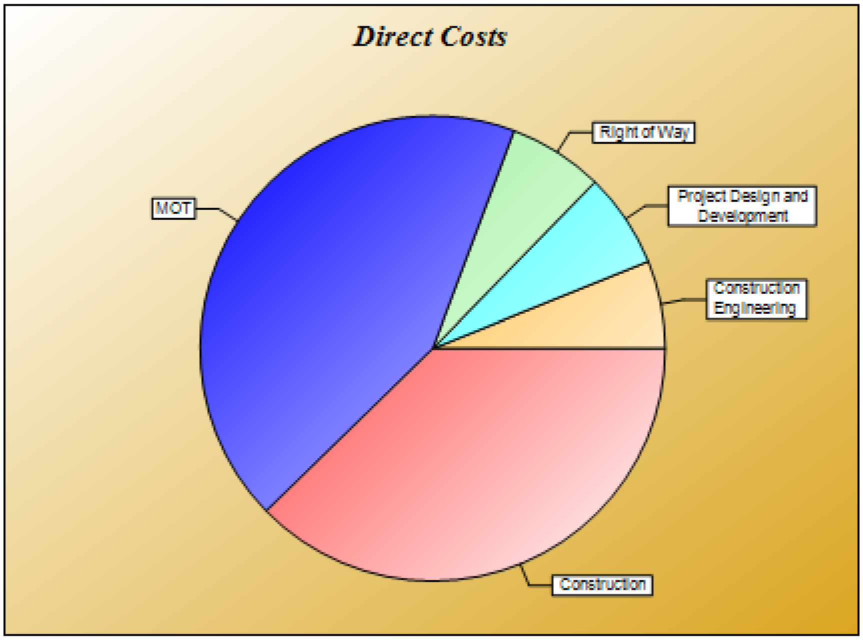


Figure 5: Sub-Criteria Weights for Direct Costs

Figures 6 and 7 summarize the results for the “Customer Service” category. Figure 6 shows that the PCC alternative is highly preferred when only customer service criteria are considered. Figure 7 highlights that “Public Relations” and “Public Perception” both have the same impact on this preference in this category.

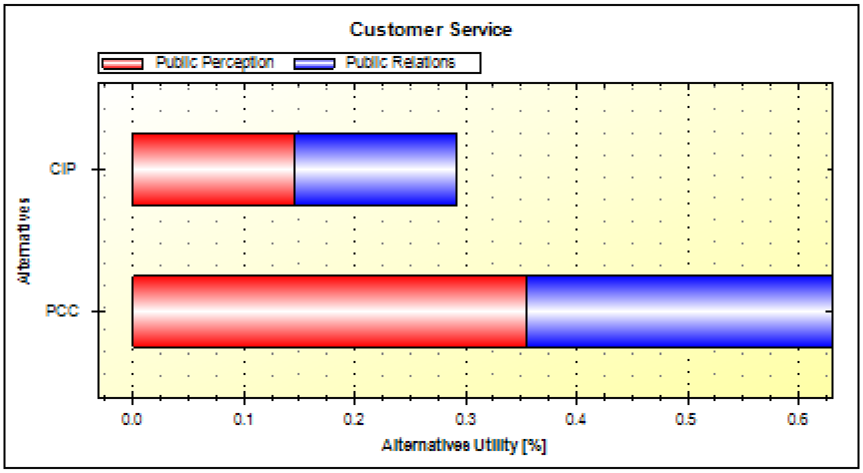


Figure 6: Ranks for Customer Service

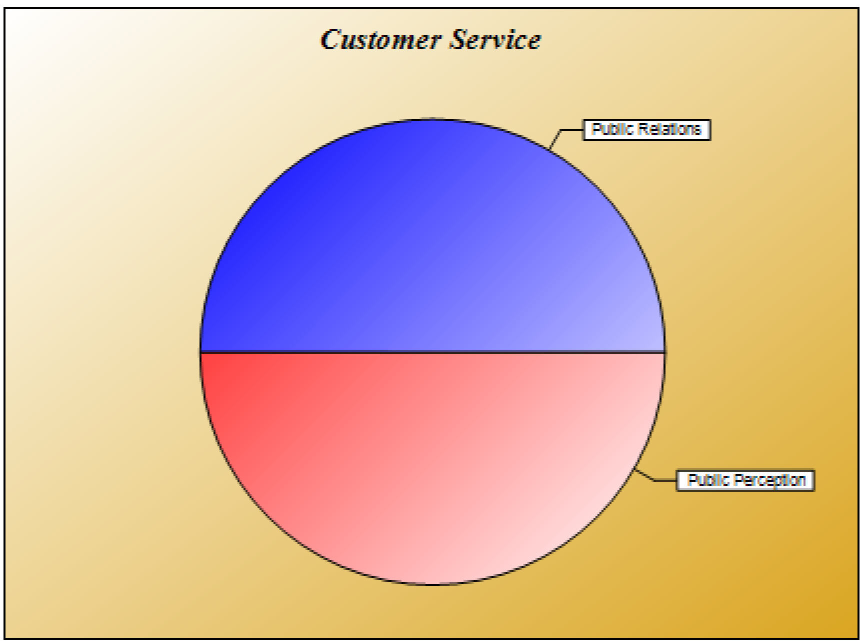


Figure 7: Criteria Weights for Customer Service

The analysis results related to the "Schedule Constraints" category are shown in Figures 8 and 9. As it is indicated, there are no sub-criteria in this category and both alternatives have the same priority with regard to schedule constraints.

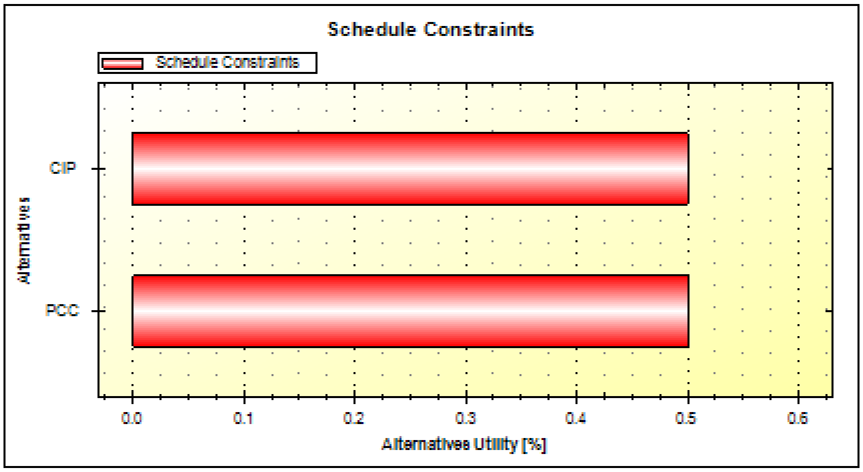


Figure 8: Ranks for Schedule Constraints

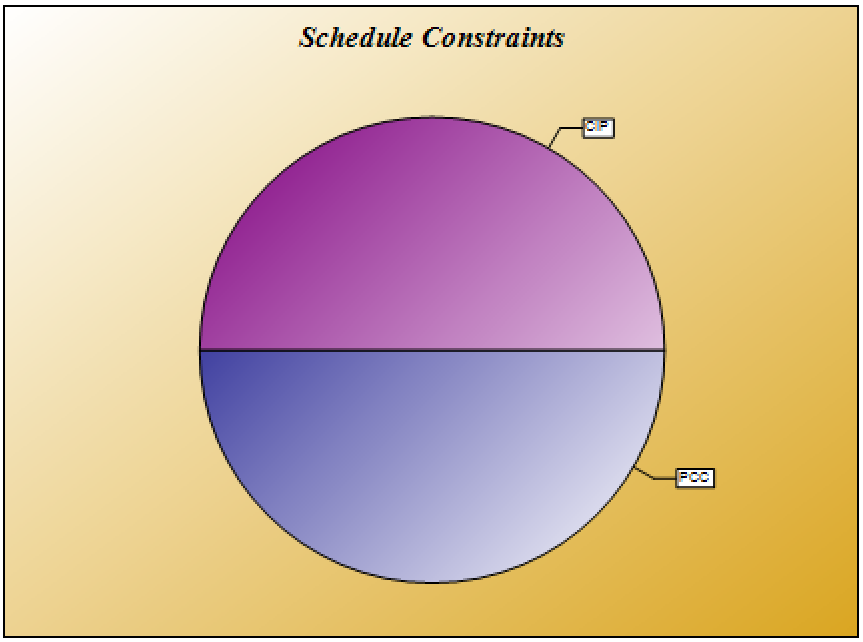


Figure 9: Alternative preference with regard to Schedule Constraints

Figures 10 and 11 summarize the results for the “Indirect Costs” category. In Figure 10, the amount of contribution of six sub-criteria to the alternatives utility in this category is indicated. Figure 11 highlights that “Construction Personnel Exposure” and “Road Users Exposure” are the two sub-criteria with the highest weight in the indirect costs category.

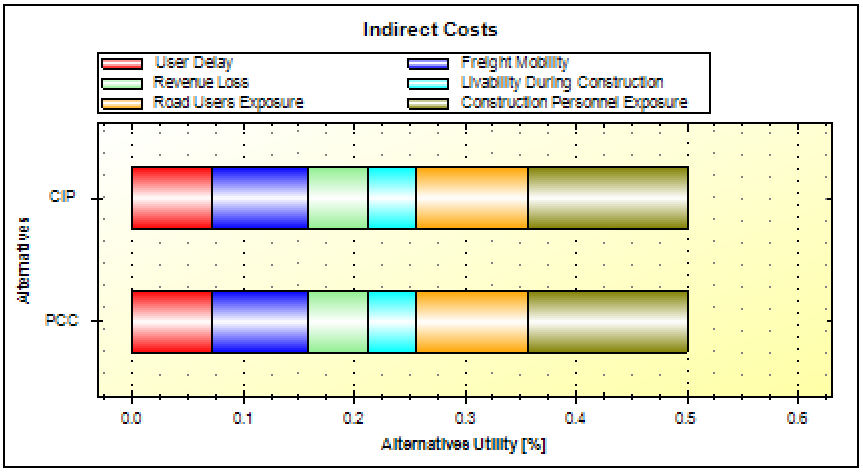


Figure 10: Ranks for Indirect Costs

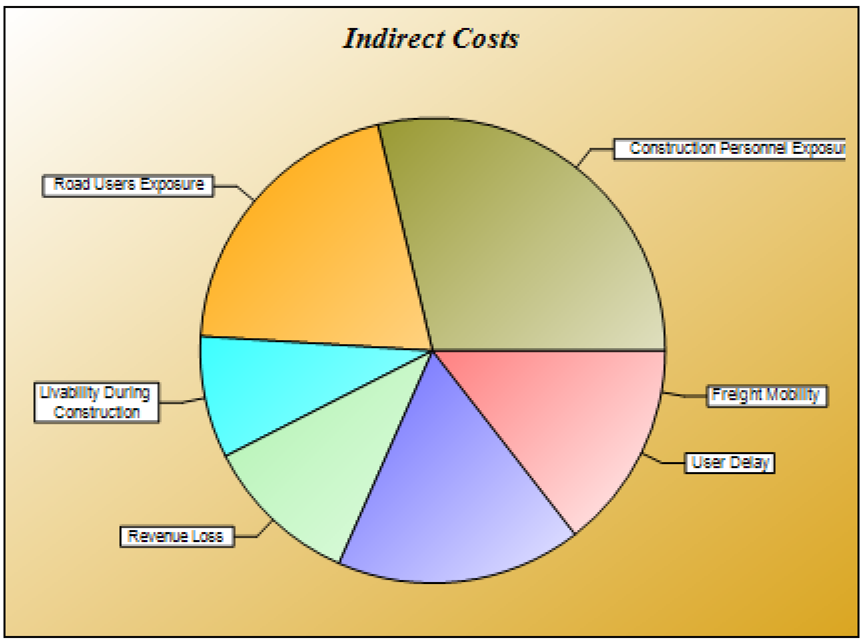


Figure 11: Sub-Criteria Weights for Indirect Costs

SR16 Eastbound Nalley Valley Interchange Project in Washington

The I5/SR16 Eastbound Nalley Valley Interchange project (EBNV) is the second project of a 3 phase interchange reconstruction. The first phase is currently under construction and replaces all the structures servicing traffic traveling north and southbound Interstate 5 onto Westbound SR16. The second phase, the EBNV project, which is currently nearing completion of the design, will replace all the structures for Eastbound SR16 traffic traveling onto south and northbound Interstate 5. The project will construct 6 new structures; 5 precast prestressed girder superstructure bridges and 1 steel plate girder bridge. The structures vary in length and width. The third and future phase of the interchange reconstruction will add HOV lanes in both direction through the interchange and will re-align Interstate 5. The interchange location is in Tacoma, WA.

On one structure, the SPN Bridge, we are requiring the Contractor to construct the cap beams as precast. The structure is 975’ long, 27’ wide with 6 spans. The SPN structure has tall single columns, up to 70’, with hammerhead type cap beams. The column reinforcement embedment length into the cap beam was reduced by taking advantage of the reduced development length when grouted into a duct, which will be cast into the cap beam. The reduction in cap beam depth reduced quantities and cost. Precast cap beams also allow the contractor to construct the beam on the ground and then lift into place, thus reducing the need for false work high up off the ground. For the SPN bridge, we are also providing the option to construct the columns as precast segments. Columns are 7’x7’ square and lengths were limited to keep the crane pick to 150 kips or less. The columns are founded on drilled shafts. The precast columns would be set into the drilled shaft and then the annular space between the larger diameter shaft and column would be filled with concrete to form the joint/connection. This connection is currently being tested at the University of Washington. One test has already been successfully performed.

One additional structure with similar characteristics, the SPS bridge, is designed as all cast-in-place, but precast crossbeam alternates are also being provided in the plans. This project is incorporating precast elements to further advance the technology and to improve constructability. There are several stages to the project and we are hopeful the precast elements will reduce durations of these stages, although overall project duration may or may not be reduced.

A Demonstration of Using ABC Decision Making Software for Nalley Valley Interchange Project

This report summarizes the AHP analysis for the Nalley Valley Interchange Project. The required data for this analysis was provided by Washington State Department of Transportation. In this study, two construction alternatives are compared: Pre-Cast Elements (PCE), which is the accelerated method and Cast-In-Place (CIP), which is the conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the PCE alternative is moderately preferable over the CIP alternative for the project. The calculated utilities for the PCE and CIP alternatives are 0.594 and 0.407, respectively.

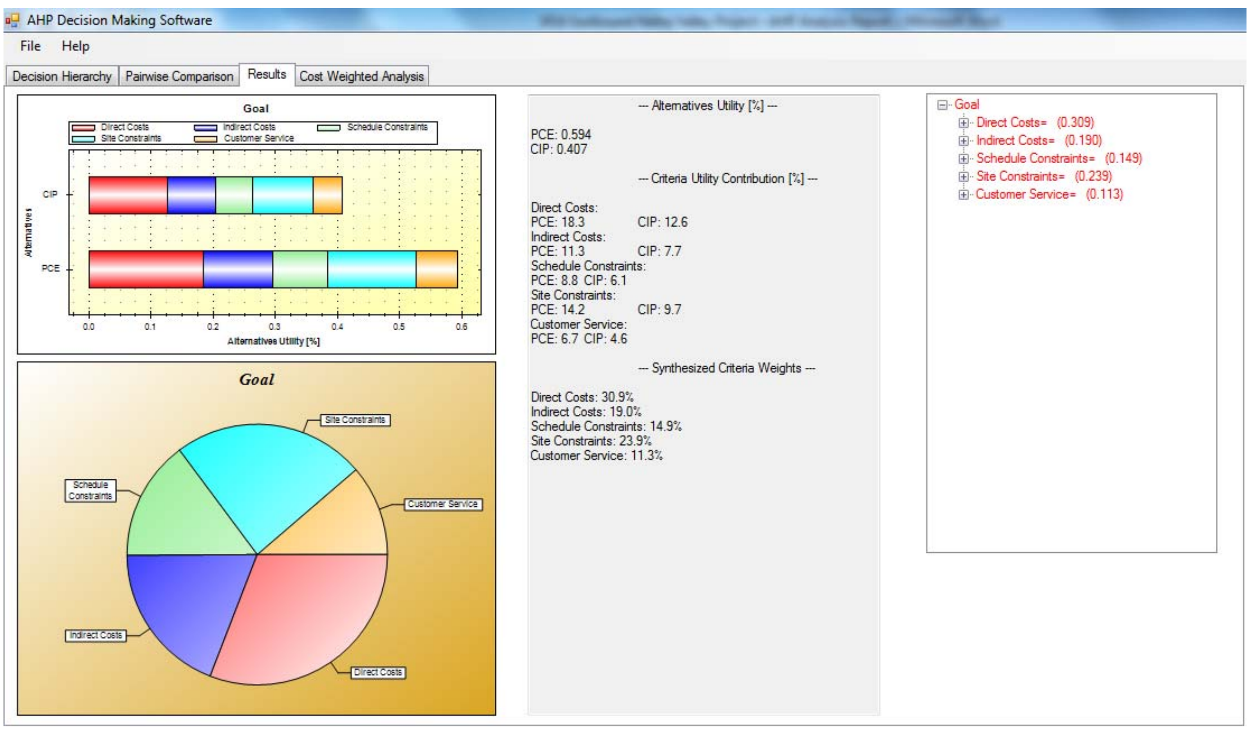


Figure 1: ABC Decision Making Software Output for the Nalley Valley Interchange Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

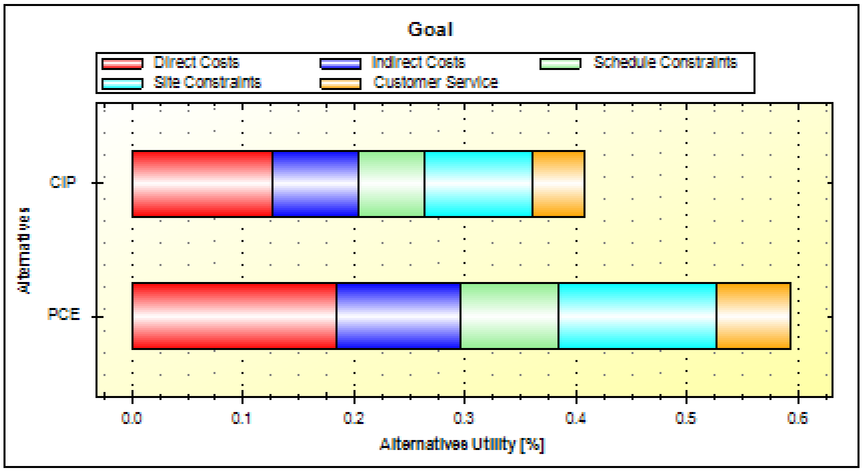


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Nalley Valley Interchange project. The results indicate that "Direct Costs" and "Site Constraints" have the greatest impact on the decision to choose PCE as the suitable alternative.

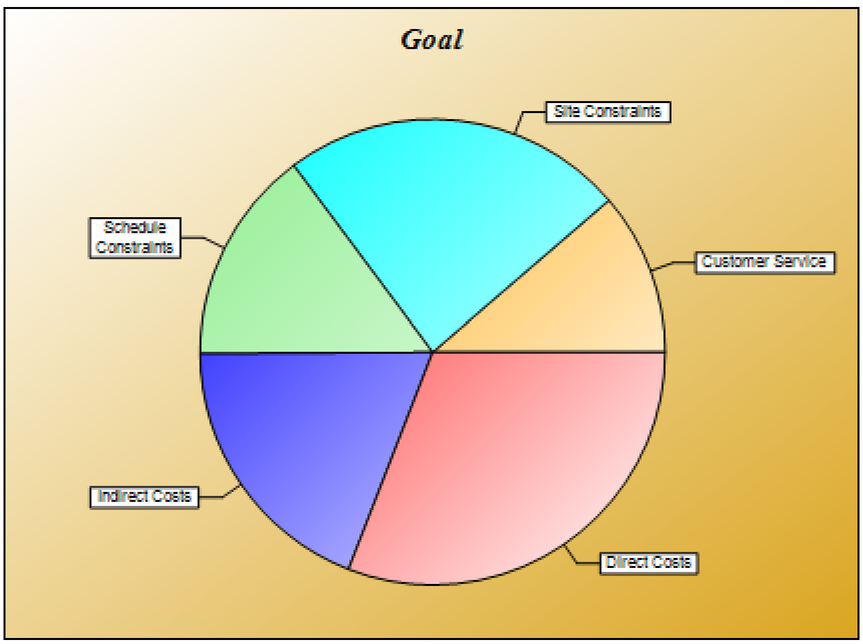


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (PCE or CIP) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 4 and 5 summarize the results for the “Direct Costs” category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 5 highlights that “Construction” has the greatest influence on the preference for PCE over CIP in the direct costs category.

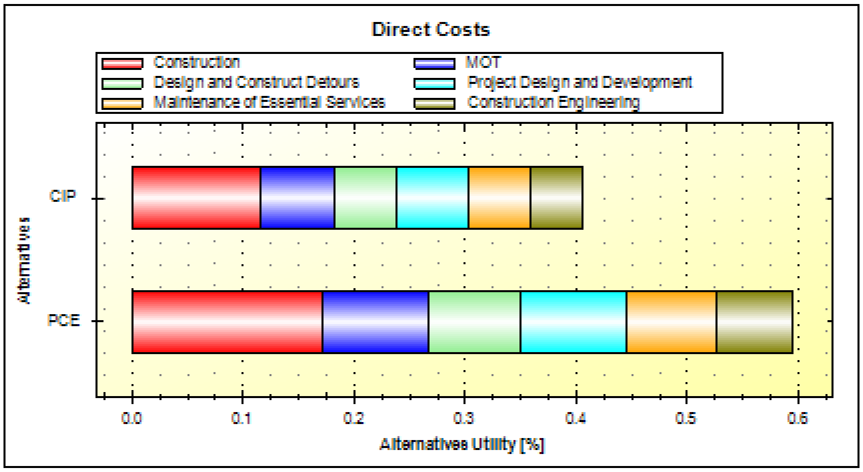


Figure 4: Ranks for Direct Costs

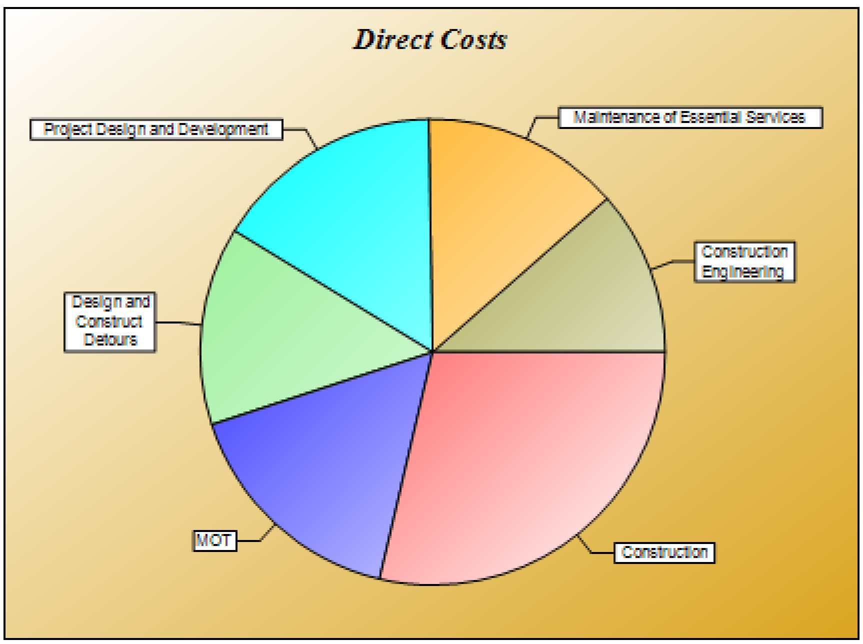


Figure 5: Sub-Criteria Weights for Direct Costs

Figures 6 and 7 summarize the results for the “Site Constraints” category. Figure 6 shows that the PCE alternative has the same preference as CIP when only site constraints criteria are considered. Figure 7 highlights that “Bridge Span Configurations” and “Horizontal/Vertical Obstructions” are the most important contributors in this category.

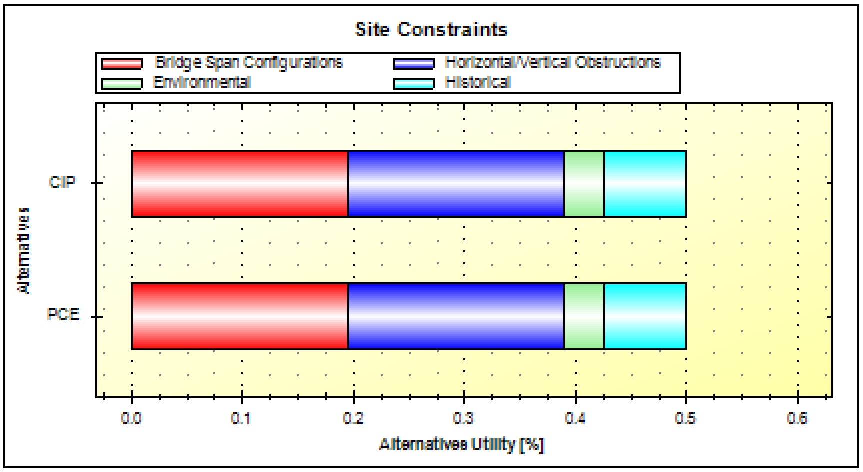


Figure 6: Ranks for Site Constraints

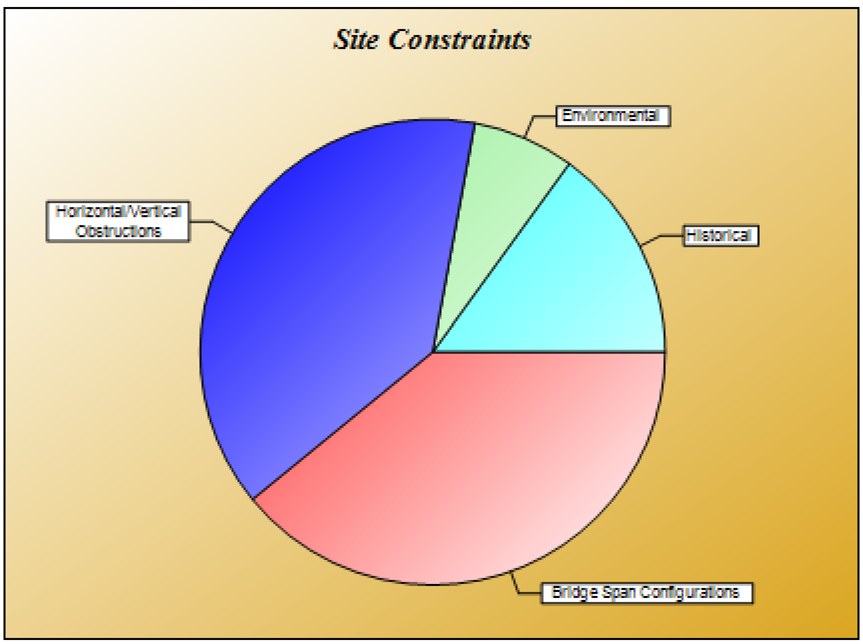


Figure 7: Criteria Weights for Site Constraints

The analysis results related to the “Indirect Costs” category are shown in Figures 8 and 9. In Figure 8, the amount of contribution of six sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that “Construction Personnel Exposure” and “Road Users Exposure” are the two sub-criteria with the highest weight in the indirect costs category.

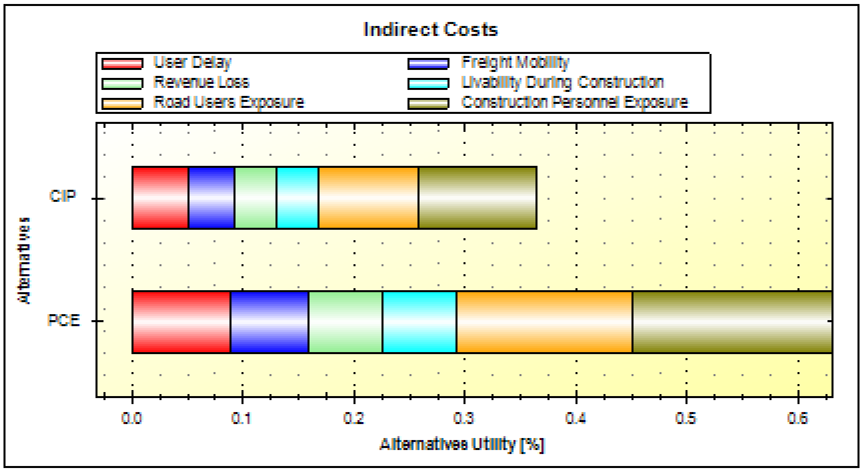


Figure 8: Ranks for Indirect Costs

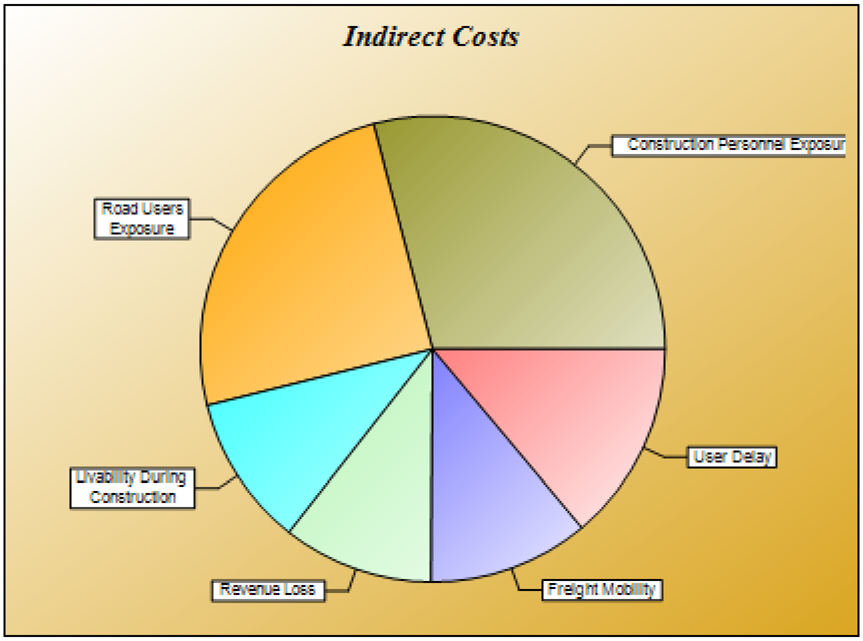


Figure 9: Sub-Criteria Weights for Indirect Costs

Figures 10 and 11 summarize the results for the "Schedule Constraints" category. Figure 10 shows that the PCE alternative is preferred when only Schedule Constraints criteria are considered. Figure 11 highlights that the most influential criterion in this category is "Calendar or Utility or R×R or Navigational".

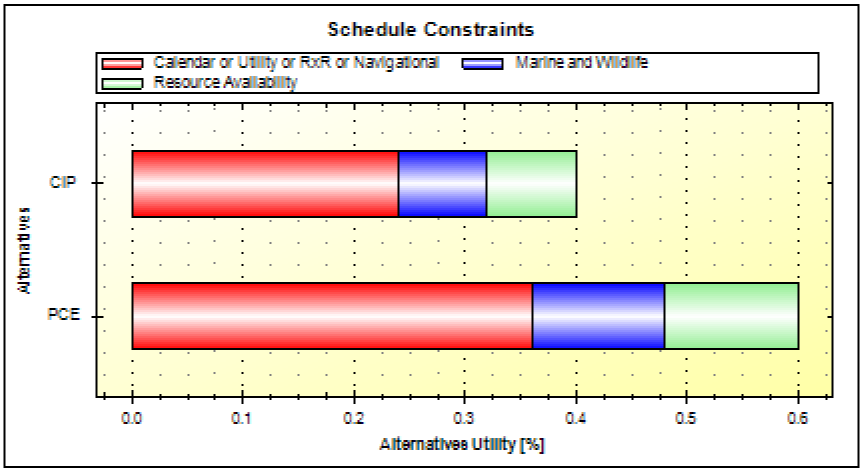


Figure 10: Ranks for Schedule Constraints

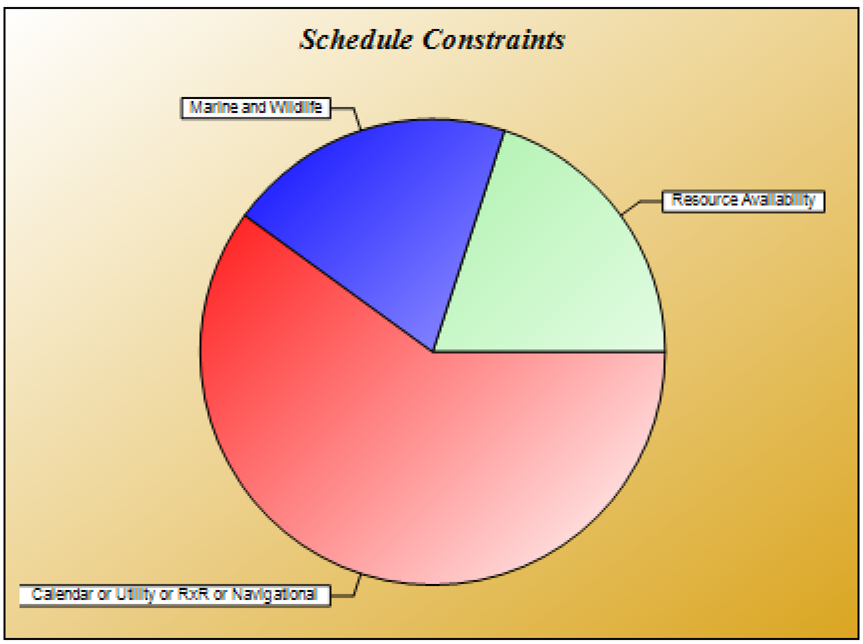


Figure 11: Sub-Criteria Weights for Schedule Constraints

The last high-level criterion is “Customer Service”. The details of this analysis are shown in Figures 12 and 13. Figure 12 indicates that the PCE alternative is highly preferred over CIP on the basis of customer service. In Figure 13, it is highlighted that “Public Relations” has the same impact as “Public Perception” on this preference.

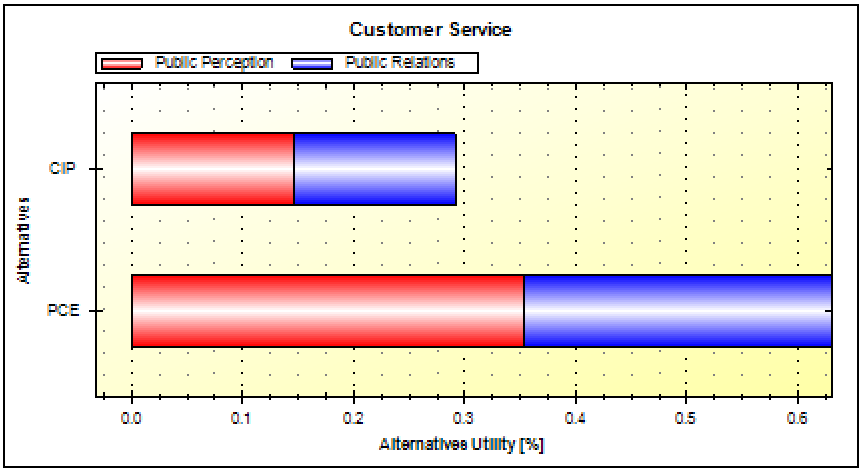


Figure 12: Ranks for Customer Service

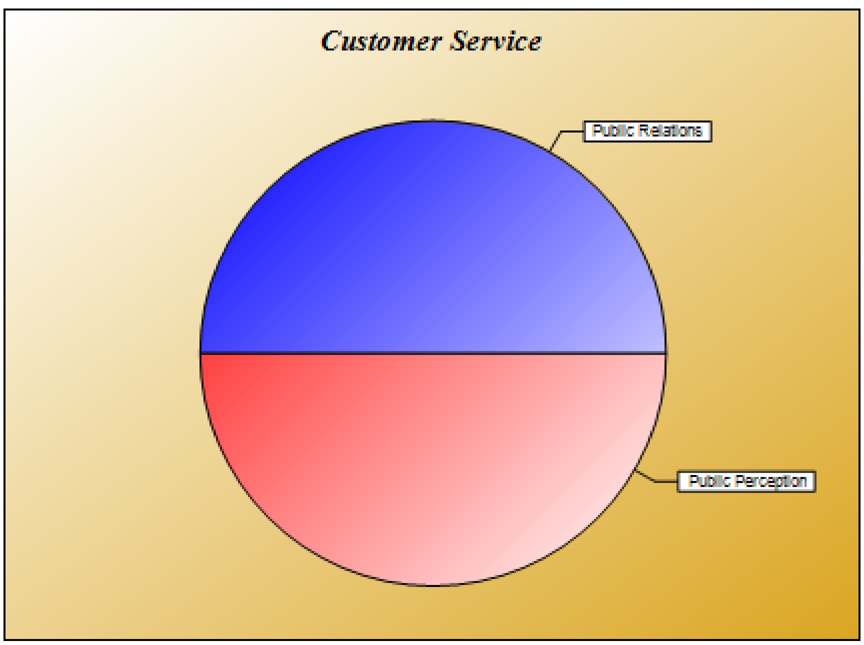


Figure 13: Sub-Criteria Weights for Customer Service

I 405, Temple Ave Project in Long Beach, California

A Demonstration of Using ABC Decision Making Software for Long Beach Project

This report summarizes the AHP analysis for the Long Beach project. The required data for this analysis was provided by California Department of Transportation. In this study, two construction alternatives are compared: Accelerated Bridge Construction method (ABC), and Conventional method.

The results summarized in this report are generated using the ABC Decision-Making software developed at Oregon State University. Figure 1 shows a screen shot from the software user interface, after analyzing the data. Based on the generated output, the ABC alternative is highly preferable over the Conventional alternative for the project. The calculated utilities for the ABC and Conventional alternatives are 0.783 and 0.217, respectively.

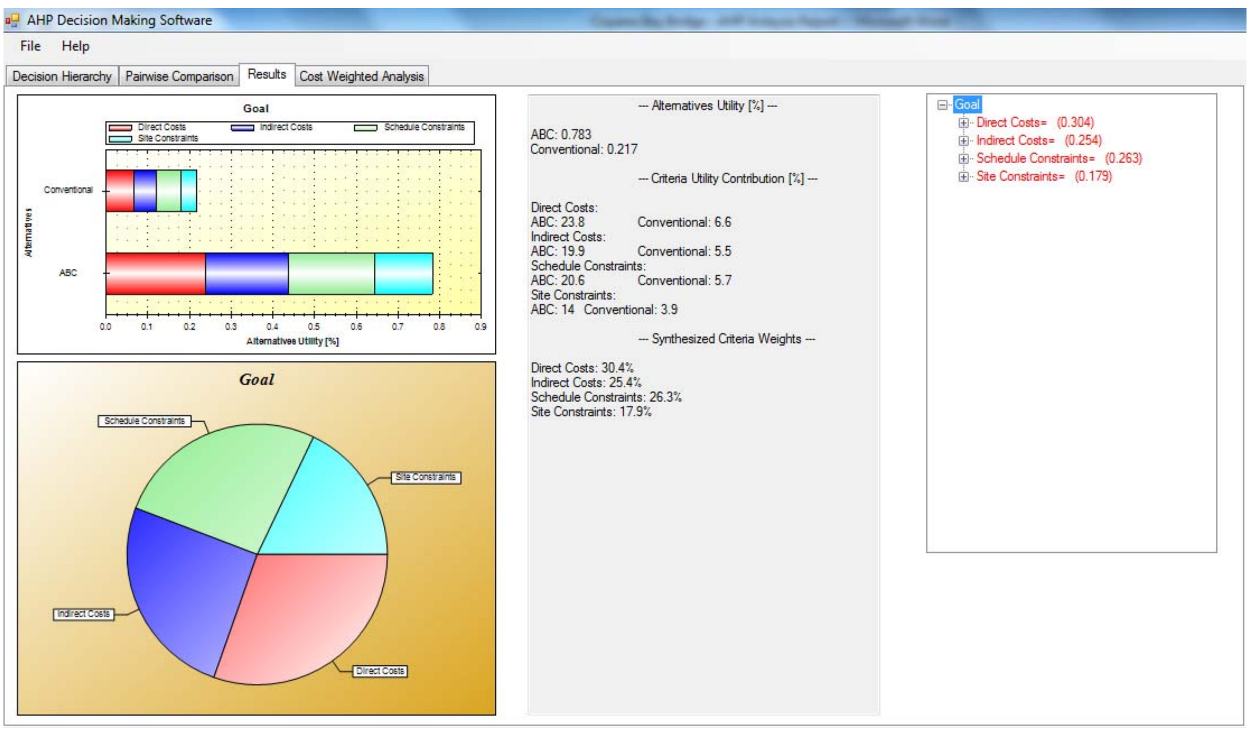


Figure 1: ABC Decision Making Software Output for the Long Beach Project

Figure 2 shows the detailed results of the AHP analysis for this project. In this Figure, the extent to which each high-level criterion contributes to the alternatives utility has been indicated. These amounts are based on the criteria weights that have been determined by the user.

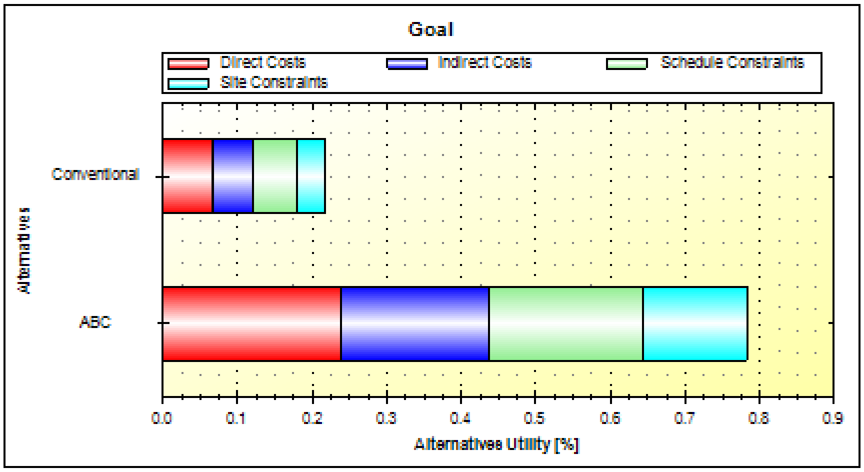


Figure 2: Criteria Utility Contribution

Figure 3 presents the high-level criteria weights for the Long Beach project. The results indicate that “Direct Costs” and “Schedule Constraints” have the greatest impact on the decision to choose ABC as the suitable alternative.

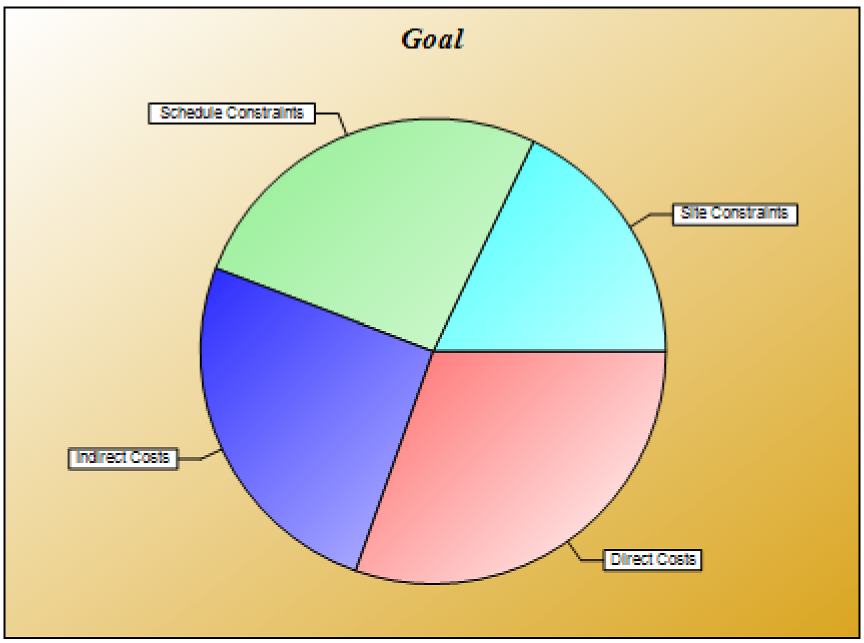


Figure 3: High-level criteria weights

In the rest of this report, the analysis results for the decision model sub-criteria are provided. For each category of criteria in the model, located at level 2, a set of two figures are presented. A bar chart shows the level of preference for an alternative (ABC or Conventional) with regard to each category. The pie-chart shows the priority of the various sub-criteria within each category.

Figures 4 and 5 summarize the results for the “Direct Costs” category. Figure 4 indicates the alternatives utility with regard to this high-level criterion. Figure 5 highlights that “Construction” and “Maintenance of Traffic” have the greatest influence on the preference for ABC over Conventional in the direct costs category.

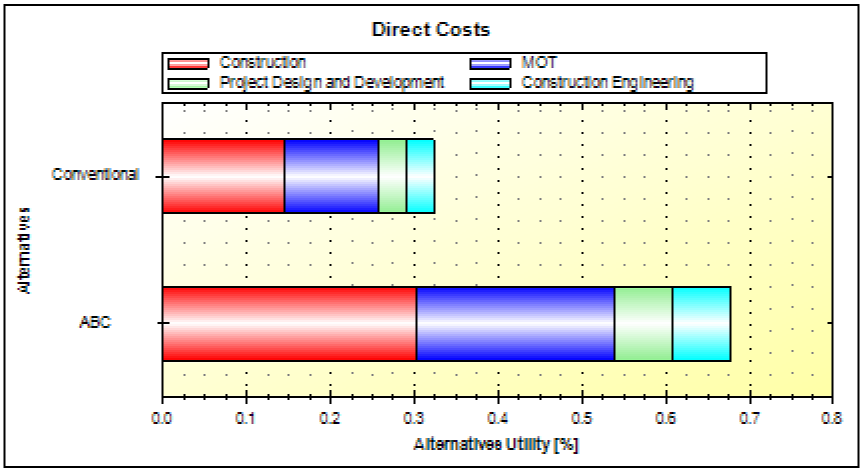


Figure 4: Ranks for Direct Costs

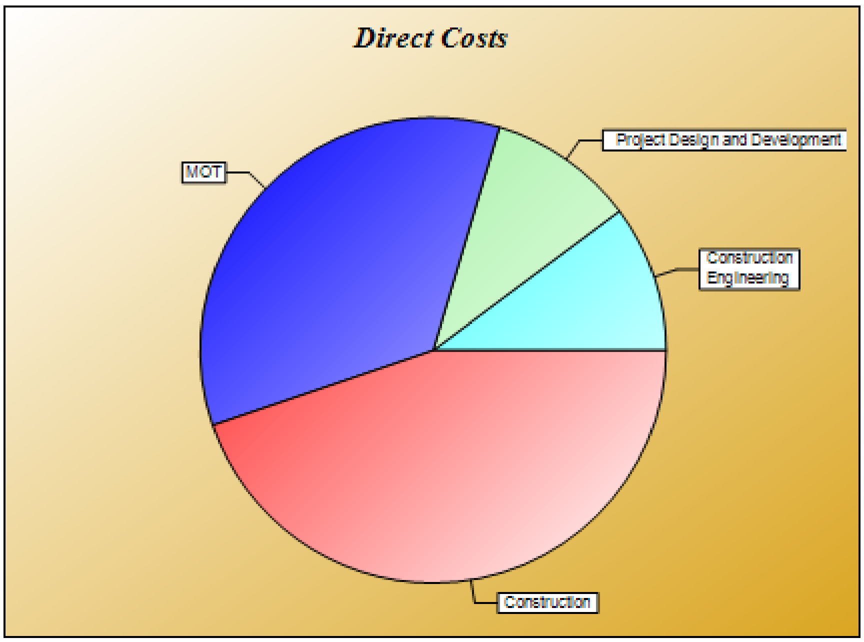


Figure 5: Sub-Criteria Weights for Direct Costs

Figures 6 and 7 summarize the results for the “Schedule Constraints” category. Figure 6 shows that the ABC alternative is highly preferred when only Schedule Constraints criteria are considered. Figure 7 highlights that “Work Window” criterion is the most important contributor to this preference.

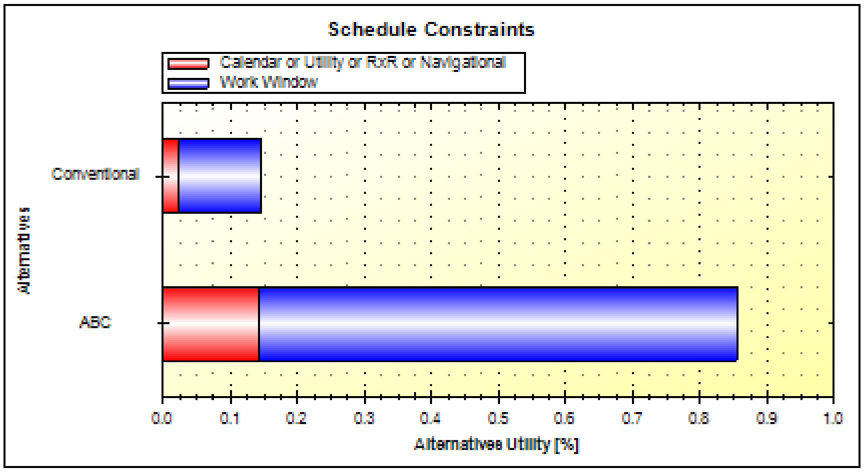


Figure 6: Ranks for Schedule Constraints

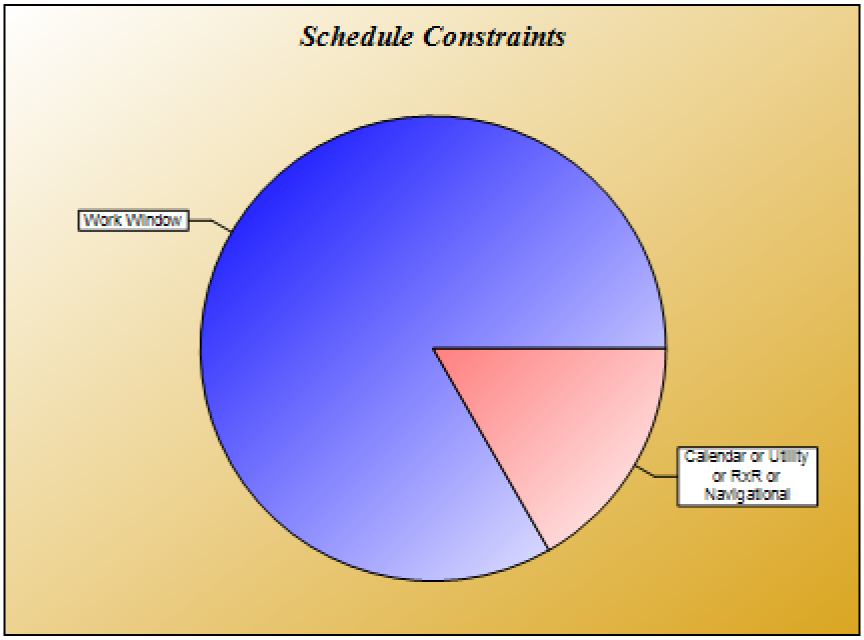


Figure 7: Criteria Weights for Schedule Constraints

The analysis results related to the “Indirect Costs” category are shown in Figures 8 and 9. In Figure 8, the amount of contribution of four sub-criteria to the alternatives utility in this category is indicated. Figure 9 highlights that “Road Users Exposure” and “Construction Personnel Exposure” are the two sub-criteria with the highest weight in the indirect costs category.

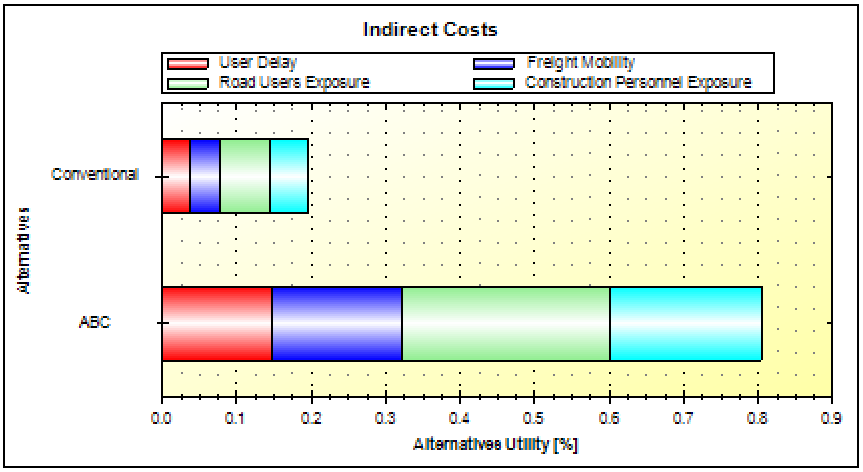


Figure 8: Ranks for Indirect Costs

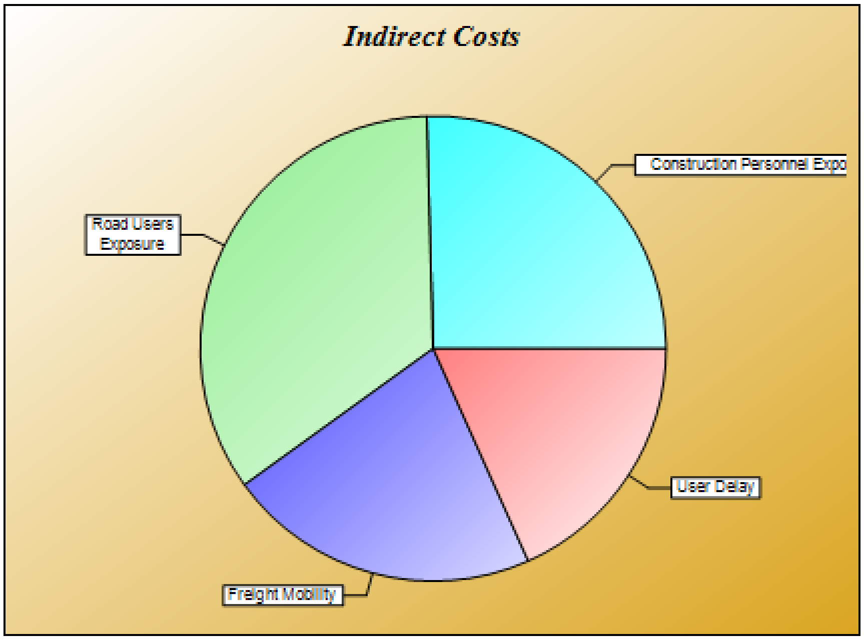


Figure 9: Sub-Criteria Weights for Indirect Costs

Figures 10 and 11 summarize the results for the “Site Constraints” category. Figure 10 shows that the ABC alternative is highly preferred when only Site Constraints criteria are considered. In Figure 11, it is highlighted that “Environmental” criterion has the greatest impact on this preference.

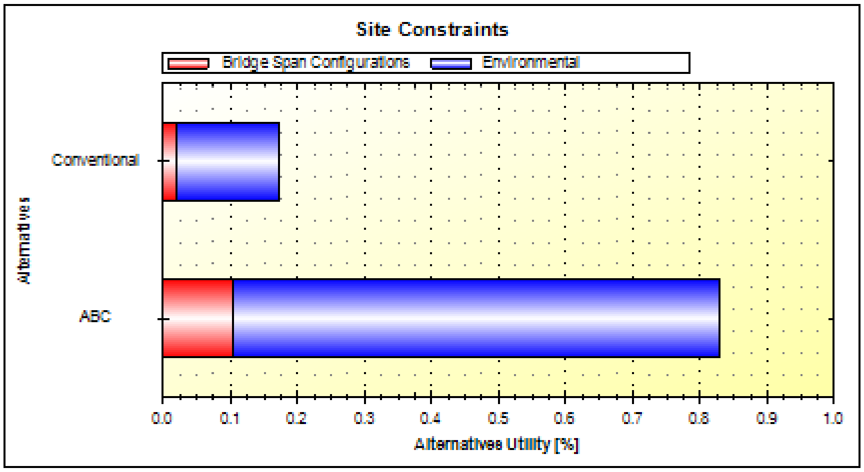


Figure 10: Ranks for Site Constraints

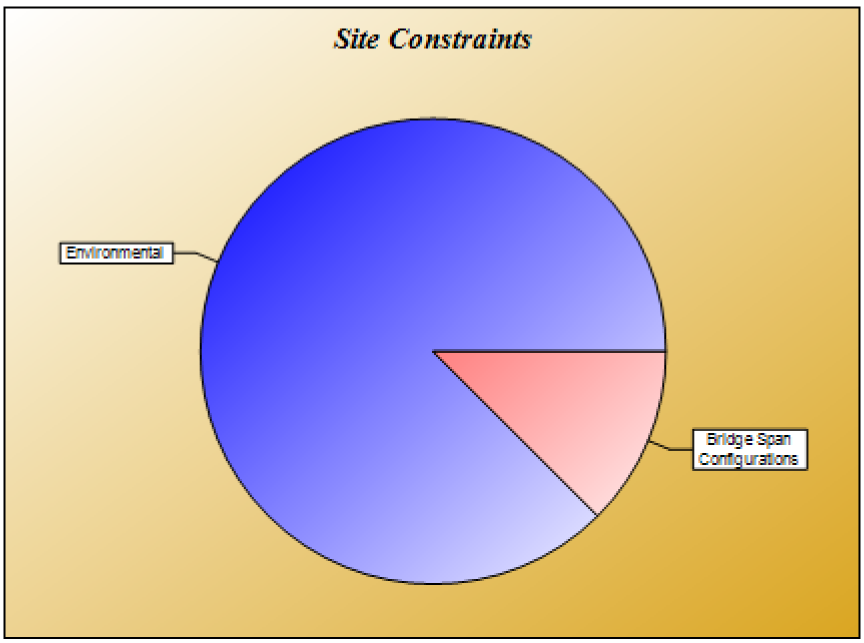


Figure 11: Sub-Criteria Weights for Site Constraints